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[illegible] Evaluation of the
[illegible] and Biological Modification
[illegible] Field Structures

by

[illegible], 2d Lt, USAF
[illegible] Fisher[illegible], 1st Lt, USAF

[illegible] 1970

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ENGINEERING EVALUATION OF THE
CHEMICAL AND BIOLOGICAL MODIFICATION
KIT FOR EXISTING FIELD STRUCTURES

by

James M. Woodruff, 2d Lt, USAF
Ronald G. Pickett, 1st Lt, USAF

FOREWORD

This test, Project 3762W004, was responsive to an Air Force Armament Laboratory (AFATL) letter, dated 1 August 1968, subject: "Test Request for CB Mod Kit for Structures." Testing was conducted from 9 December 1968 to 15 April 1969.

Personnel responsible for testing and report preparation were:

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This technical report is approved.

R. F. Todd

R. F. TODD, Colonel, USAF
Deputy for Test and Evaluation

ABSTRACT

An engineering evaluation was conducted on the CB Modification Kit for Structures. Environmental testing demonstrated the ability of the system to withstand extremes of temperature, dust, and rain. Floor buckling and corrosion prevented operation after humidity testing. CB simulant testing demonstrated that the system meets design requirements and will protect personnel with 99.6 percent efficiency in chemical simulant (Methyl Acetoacetate) concentrations up to 100 mg/m^3 and with 99.99 percent efficiency in biological simulant (Bacillus globigii) concentrations up to 10^6 cells/m^3. A C-123 aircraft will accommodate the service module and three filter-blower units.

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ILLUSTRATIONS AND TABLES

ILLUSTRATIONS AND TABLES (Continued)

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SECTION I

INTRODUCTION

The purpose of this project was to conduct an engineering evaluation of the CB Modification Kit for Structures, a CB defensive item.

The test objectives were to:

1. Determine the ability of the CB Modification Kit for Structures to withstand the following extreme environments as specified in MIL-STD-810B, Military Standard Environmental Test Methods, dated 15 June 1967:

   a. High temperature
   b. Low temperature
   c. Humidity
   d. Dust
   e. Rain.

2. Evaluate the capability of the CB Modification Kit to protect personnel in a simulated CB agent environment.

3. Evaluate the CB Modification Kit from a human factors standpoint.

4. Insure CB Modification Kit C-123 air transportability.

All objectives were accomplished.

SECTION II

DESCRIPTION

OPERATIONAL CONFIGURATION

The CB Modification Kit for Existing Air Force Field Structures (Figure 1) consists of a service module with airlocks and decontamination facilities and three filter-blower units which provide filtered air to maintain 0.4 to 0.6 inch of water gage (IWG) overpressure.

The kit provides the necessary sealing, air purification, pressurization, ingress/egress, and decontamination capability to insure CB protection for personnel in a CB agent environment. The kit is a removable modification to a structure and will not inhibit the normal function of the structure. The kit can be made independent of external power and water for a limited period of time by use of a 15-kilowatt (KW) capacity, standard gasoline engine-driven generator. It is designed to be air transportable on a C-123 or larger cargo aircraft.

An operational kit contains a collapsible prefabricated, transition section which connects the modification kit to the building to be protected and sealing compound to reduce the building's natural leak rate. Those components were not a part of this test.

The modification kit, as supplied with three filter-blower units, is designed to protect buildings with up to 20,000 cubic feet volume. By employing a maximum of three additional filter-blower units, buildings with up to 40,000 cubic feet volume can be protected.

SERVICE MODULE CONSTRUCTION

The service module is an aluminum frame, stressed aluminum skin, structure mounted on extruded aluminum skids. Its dimensions are: length, 12 feet; width, 7 feet; and height, 7 feet 4 inches. It weighs 3,000 pounds. It has double-wall construction and is insulated with 2.75-inch-thick rigid polyurethane foam in the walls, floor, and ceiling. The interior aluminum wall surfaces are finished with a gloss white polyurethane base enamel.

The service module is divided into seven compartments. They are entrance airlock, undressing room, shower stall, service compartment, dressing room, plenum chamber, and exit airlock.

The modification kit has a decontamination system (shower), an air heating system, an electrical system, a control system which regulates personnel entrance, and an air pressurization system.

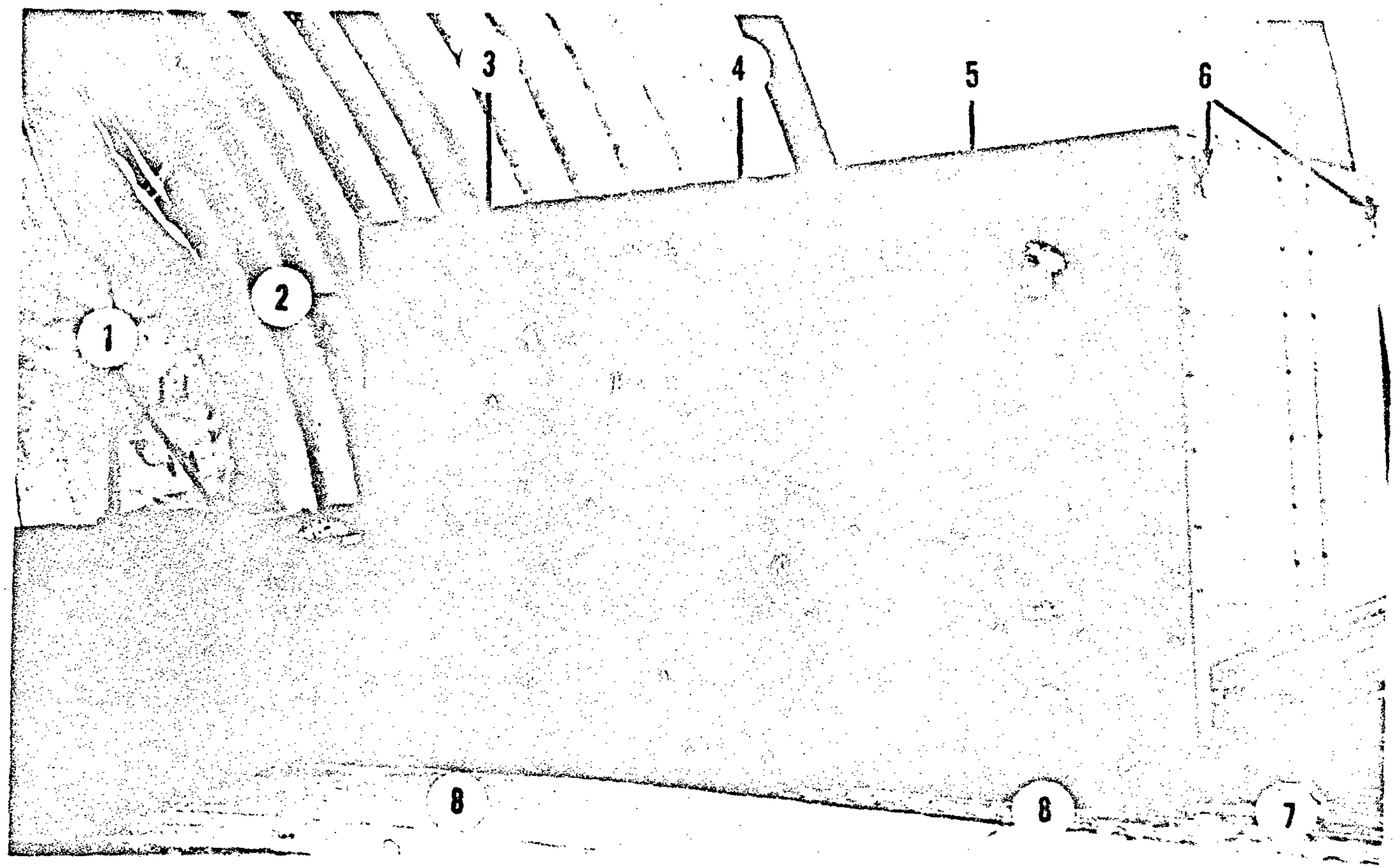

Figure 1. CB Modification Kit for Structures: (1) filter-blower units, (2) service module, (3) exit airlock, (4) water inlet fitting, (5) entrance airlock, (6) lifting rings, (7) tie-down rings, and (8) adjustable air outlets

AIRLOCKS

Separate entrance and exit airlocks eliminate interference between entering and exiting personnel. The two airlocks are similar except for the lights in the entrance airlock which regulate personnel entry (Figure 2).

Each airlock is 3 feet long, 3 feet wide, and 6 feet 6 inches high inside. The inner and outer airlock doors have a fiberglass laminate skin and a foamed-in-place polyurethane core. Each door is self-closing through the use of a conventional overhead hydraulic door closer.

The inner and outer doors of each airlock are mechanically interlocked so that one door cannot be opened until the other is securely closed (Figure 3). There are removable pins on both sides of each airlock which permit the interlock system to be bypassed in case of emergency or malfunction.

The exterior doors are latched by walk-in cooler latches with plunger releases on the inside. The interior doors are pushed or pulled open after the interlock has released.

Air flows into the airlock from the interior of the service module through a damper in the ceiling. The damper is normally open but closes automatically when the outer door opens. Air flow through each airlock is controlled by an outlet near the bottom of each outer airlock door which is adjusted to give a pressure differential of 0.4 to 0.6 inch of water gage (IWG). This is equal to an airflow of approximately 100 cubic feet per minute (CFM).

PERSONNEL CONTROL SYSTEM

Personnel entry into the service module is controlled to allow purging of contamination from the airlock and allow enough time for an entrant to clear the undressing room before another tries to enter. A time-delay relay controls each function with WAIT and ENTER lights in the entrance airlock. Switches on the airlock door jambs sense the entry and passage of personnel and energize the relays.

PERSONNEL DECONTAMINATION SYSTEM

Upon leaving the entrance airlock, the entrant enters a 4-foot by 3-foot undressing compartment (Figure 4). Unless he is wearing complete safety attire he will discard all garments, except his protective mask, through a clothes disposal chute. An entrant wearing complete safety attire will pass through the undressing room into the shower without disrobing.

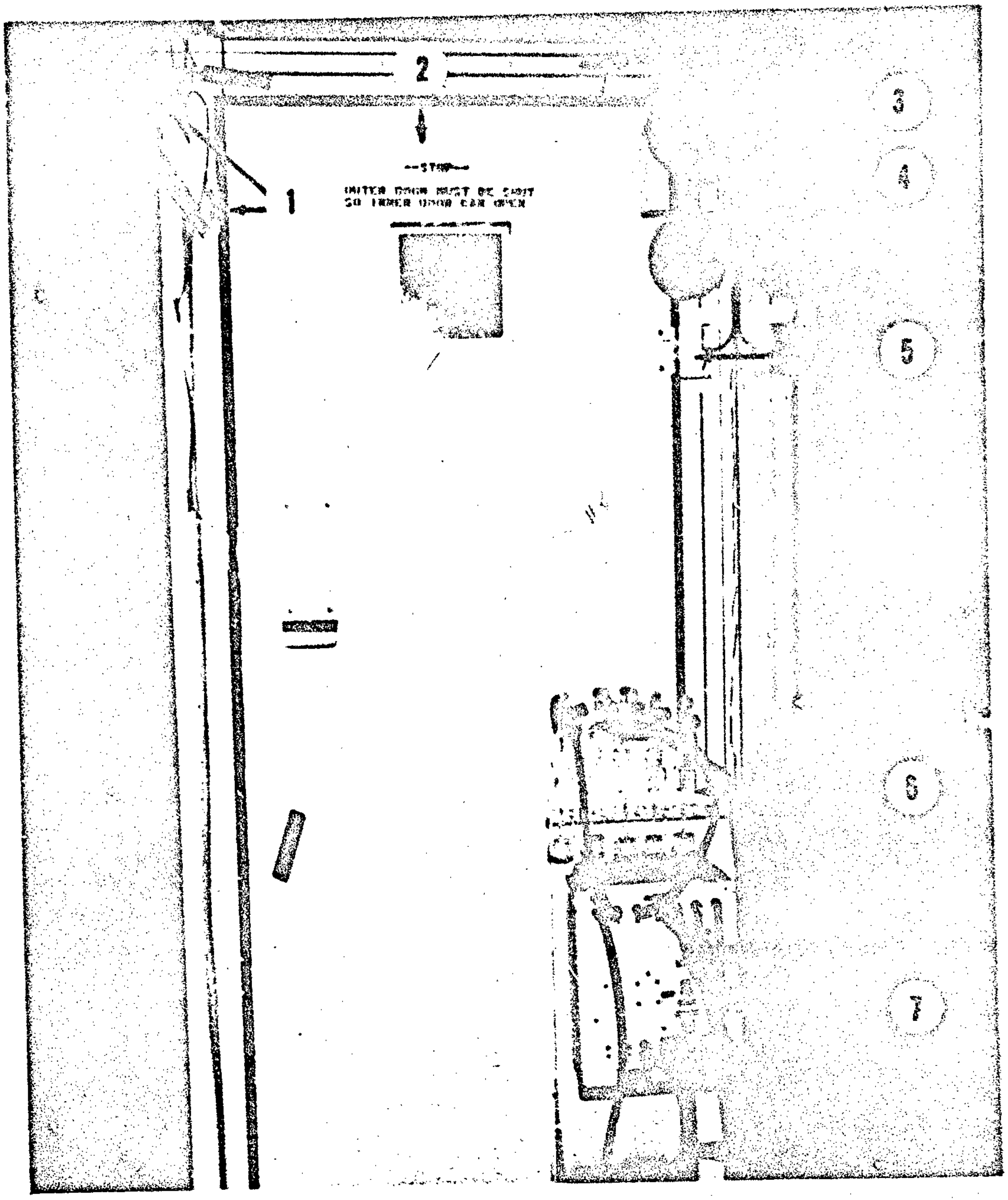

Figure 2. Entrance airlock of service module: (1) door interlocks, (2) inner airlock door, (3) personnel entrance control lights, (4) damper and light control switch, (5) light control switch, (6) 12.5 liter per minute all-glass impingers with pre-impingers (for simulant testing), and (7) vacuum manifold sequencer (for simulant testing)

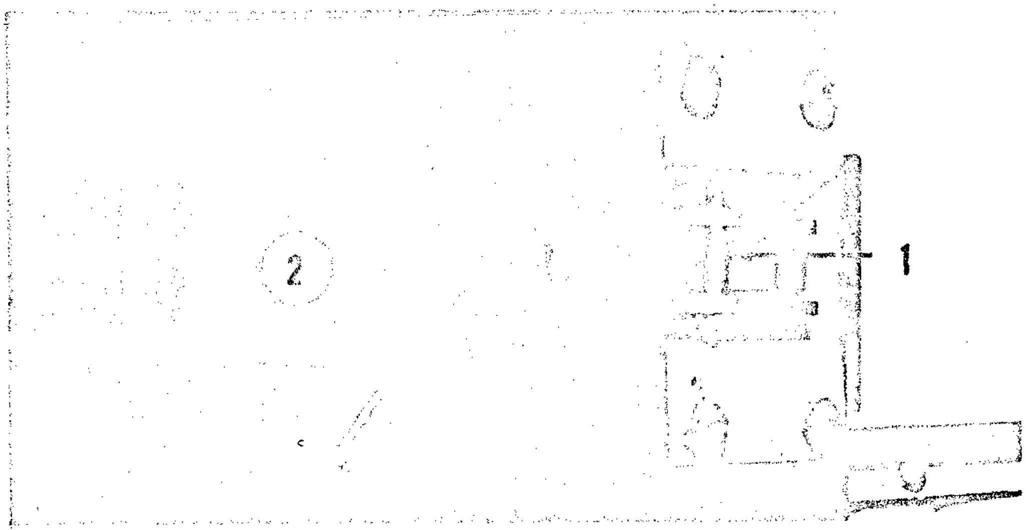

Figure 3. Door interlock (1) with removable bypass pin (2)

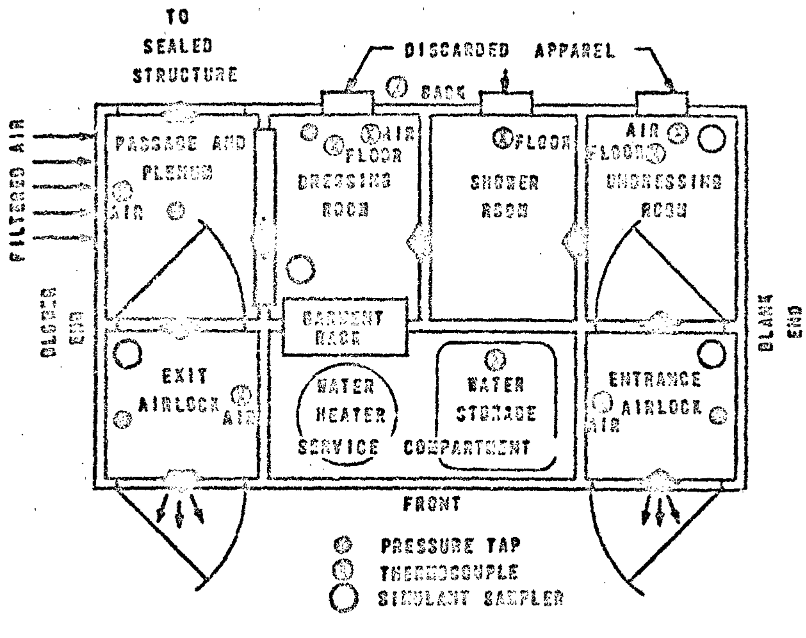

Figure 4. Floor plan of service module, showing location of pressure taps, thermocouples, and simulant samplers.

Three disposal chutes are provided, one each in the undressing, shower, and dressing compartments. Each chute is an opening in the back wall of the modification kit. A door with a spring-type hinge and a rubber gasket seals the opening on the inside. A plastic garbage bag is taped to the outside and placed in a 26-gallon (or larger) capacity garbage can.

The shower subsystem consists of a 155-gallon water storage tank, an electric water pump, and a 52-gallon electric water heater which are located in the service compartment, and a 4-foot by 3-foot shower stall. The storage tank allows the modification kit to operate independently of an external water supply in time of emergency.

A push-type switch, located in the shower stall, controls the pump which supplies water to the shower head at 3 to 5 gallons per minute (gpm). The shower will operate continuously for a period of at least 31 minutes. The shower water temperature can be varied between 60°F and 120°F with a knob in the shower stall. Two panels with spring-type hinges unfold from the shower wall to contain the water in the shower. A drain in the floor of the shower stall carries effluent water out of the modification kit.

A 4-foot by 3-foot dressing room is located next to the shower. It contains a removable utility cabinet for towels and clothing, an emergency lighting unit mounted on the ceiling, and the main electrical control panel.

An entrant wearing full protective equipment over conventional clothing would shower to wash off contamination and then dispose of the protective garments by putting them through the disposal chute. He would then pass through the dressing room and into the building. A nude occupant would shower and then discard his protective mask through the disposal chute before entering the dressing room. He would then remove a towel from the cabinet and dry off, discard the towel through the disposal chute, and dress, taking garments from the utility cabinet.

AIR PRESSURIZATION SYSTEM

The air pressurization system consists of the filter-blower units, an influent air panel located on the side of the modification kit, and flexible ducts which connect the filter-blowers to the panel.

Each filter-blower unit is composed of a blower fan, a commercial prefilter, a particulate filter, and a gas filter. The blower fan is a direct-drive, radial blade, centrifugal fan powered by a 1-horsepower, 208-220-volt, 60-hertz (Hz), 3-phase motor.

The prefilter is a standard coarse particulate filter, normally found in home air conditioners and furnaces. The particulate and gas filters are standard units developed by the US Army Chemical Corps. A 1200-cfm C19R1 particulate filter (MIL-F-51215A) is used in series with a 600-cfm M14A1 gas filter (MIL-F-51224A, Amendment 1) in order to achieve equivalent filter

life spans. Each filter-blower unit will supply filtered air to the modification kit at a rate of 600 cfm. The components are mounted in series, on a skid-type frame (Figure 5).

The flexible ducting used to connect the filter-blower to the influent air panel is 13 inches in diameter and supplied in 10-foot lengths. It is made of butyl-coated nylon and is helical wire reinforced. It can be collapsed to a length of approximately 2.5 feet for storage and is fastened to flanges on the filter-blower and the influent air panel with screw-type clamps. The influent air panel is located on the side of the modification kit at the plenum chamber. It has six flanges on it to which the flexible ducts from the filter-blower units are attached. The unused flanges are capped.

The flow of filtered air, entering the modification kit through the influent air panel, is split in the plenum chamber. The bulk of the filtered air flows from the plenum chamber directly into the building protected. One hundred cfm flows into the other compartments of the modification kit through a perforated door located between the dressing room and the plenum chamber. This air eventually flows through a ceiling duct into the entrance airlock.

AIR HEATING SYSTEM

The perforated door between the dressing room and plenum chamber contains electrical strip heaters which heat air entering the modification kit. There are 5 banks of heaters which are controlled by a 6-position selector switch located on the electrical control panel. The heaters are designed to raise the temperature of air entering the modification kit at -25°F to +60°F.

ELECTRICAL SYSTEM

The modification kit requires 208-240-volt, 60-Hz, 3-phase, 4-wire power source with approximately 15-kilowatt (kw) capacity at peak demand. A portable gasoline engine-driven generator, common to Air Force inventory, will fulfill this requirement.

Power is supplied to the modification kit through a standard aircraft 400-Hz plug at an external junction box. Power is routed to the main electrical control panel where it is fed to the pressurisation, air heating, water, and lighting subsystems.

The main electrical control panel contains six circuit breakers to control up to six filter-blower units. Power is fed back to the external junction box where there are six common plugs to which the filter-blower power cords are connected. There are also a 110-volt utility plug, the air heater selector switch, and circuit breakers for the water heater, air heater, lights, [illegible], and shower pump.

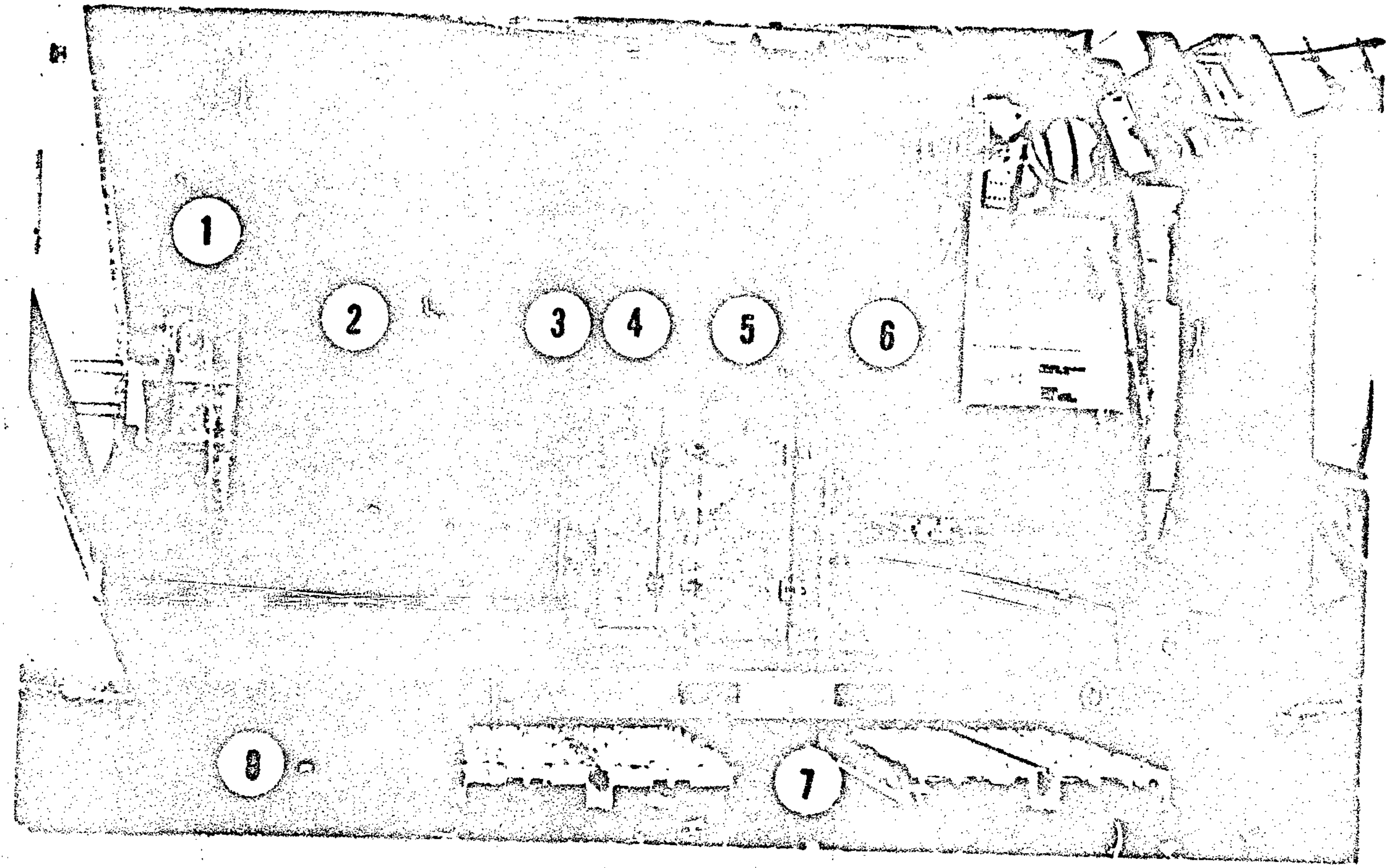

Figure 5. CB Modification Kit for Structures loaded on C-123 aircraft: (1) service module, (2) blower fan, (3) filter-blower unit, (4) prefilter access door, (5) particulate filter, (6) gas filter, (7) slots for forklift handling, and (8) tie-down rings

TEST CONFIGURATION

For testing purposes a plywood panel with three adjustable orifices (Figure 6) was attached by the contractor to the doorway which would ordinarily lead to the building to be protected. This building simulator was adjusted by the contractor to be used in conjunction with one filter-blower unit.

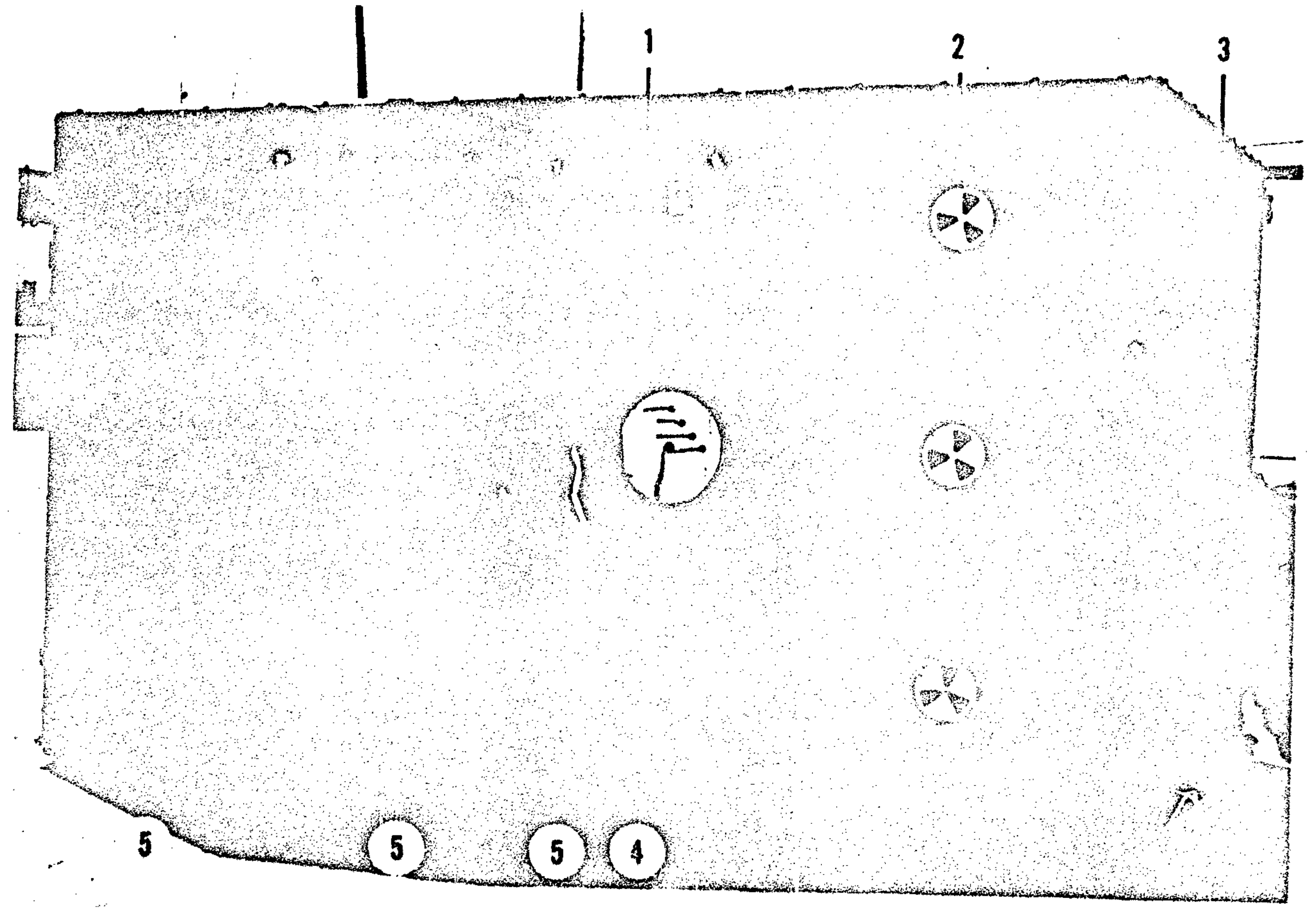

Figure 6. Rear of service module: (1) modification kit power input and blower power output, (2) building simulator with adjustable orifices, (3) influent air panel, (4) instrumentation output, and (5) clothes disposal outlets

SECTION III

INSTRUMENTATION

CARGO FIT TESTING

Cargo fit testing was conducted at the Hurlburt Field flightline using a C-123 cargo aircraft and 463L cargo-handling equipment, including wheel conveyors, a 108-inch by 88-inch pallet, and a Rough Terrain Loader with 10,000-pound capacity. The forklift was equipped with roller conveyer forks.

ENVIRONMENTAL TESTING

All environmental testing was accomplished utilizing facilities of the Eglin Air Force Base Climatic Laboratory.[1]

Low temperature testing was conducted in the Main Chamber. The high temperature and dust tests were accomplished in the All-Weather Room. Humidity testing was conducted in the Salt Spray Chamber. The rain test was conducted utilizing a portable rain facility and wind machine.

The temperatures at various points within the modification kit (Figure 4) were measured with ten copper Constantan thermocouples connected to a strip chart recorder. The air pressure in the compartments of the modification kit was measured using differential pressure gauges calibrated in inches of water and connected to the modification kit with plastic tubing. The voltage, current, and power requirements of the modification kit were measured with an industrial analyzer.

SIMULANT TESTING

The chemical and biological simulant tests utilized a "C" generator and two nebulizers to generate and maintain the simulant cloud and an inflatable rubber shelter to contain the cloud. Aerosol samples were collected at various points inside and outside the modification kit (Figure 6), using 12.5-liter-per-minute, all-glass impinger (AGI-30) samplers, connected to a vacuum manifold which could be remotely sequenced. During the biological simulant test the impingers were equipped with 5-micron pre-impingers. Temperature and pressure within the modification kit were monitored in the same manner as during environmental tests.

[1] See Air Proving Ground Center Technical Facilities Vol. I, April 1967.

SECTION IV

TEST PROCEDURES

Two complete modification kits were provided as test items. The first modification kit was used for cargo fit testing and all environmental tests except the rain test. The second modification kit was used for the simulant challenges and the rain test.

CARGO FIT TESTING

The service module was placed on a 108-inch by 88-inch standard cargo pallet and strapped down (Figure 7). Two rows of double conveyor were placed on the floor and ramp of the aircraft, and the parachute static lines were partially removed. The service module was picked up at one end by a forklift and secured with cargo tie-down straps to prevent it from tipping off the end of the forks. The service module was maneuvered into the cargo hatch of the C-123 aircraft (Figure 8). When the bottom of the service module was even with the conveyors on the ramp of the aircraft, the tie-down straps were removed and the unit was pushed off the forklift onto the conveyors. The three filter-blower units were loaded behind the service module.

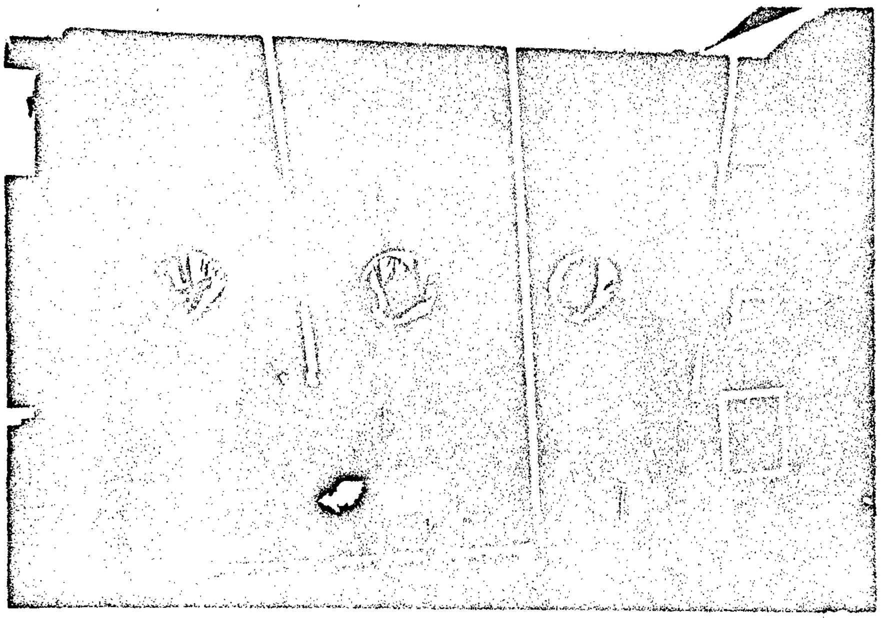

Figure 7. Service module loaded on 463L pallet

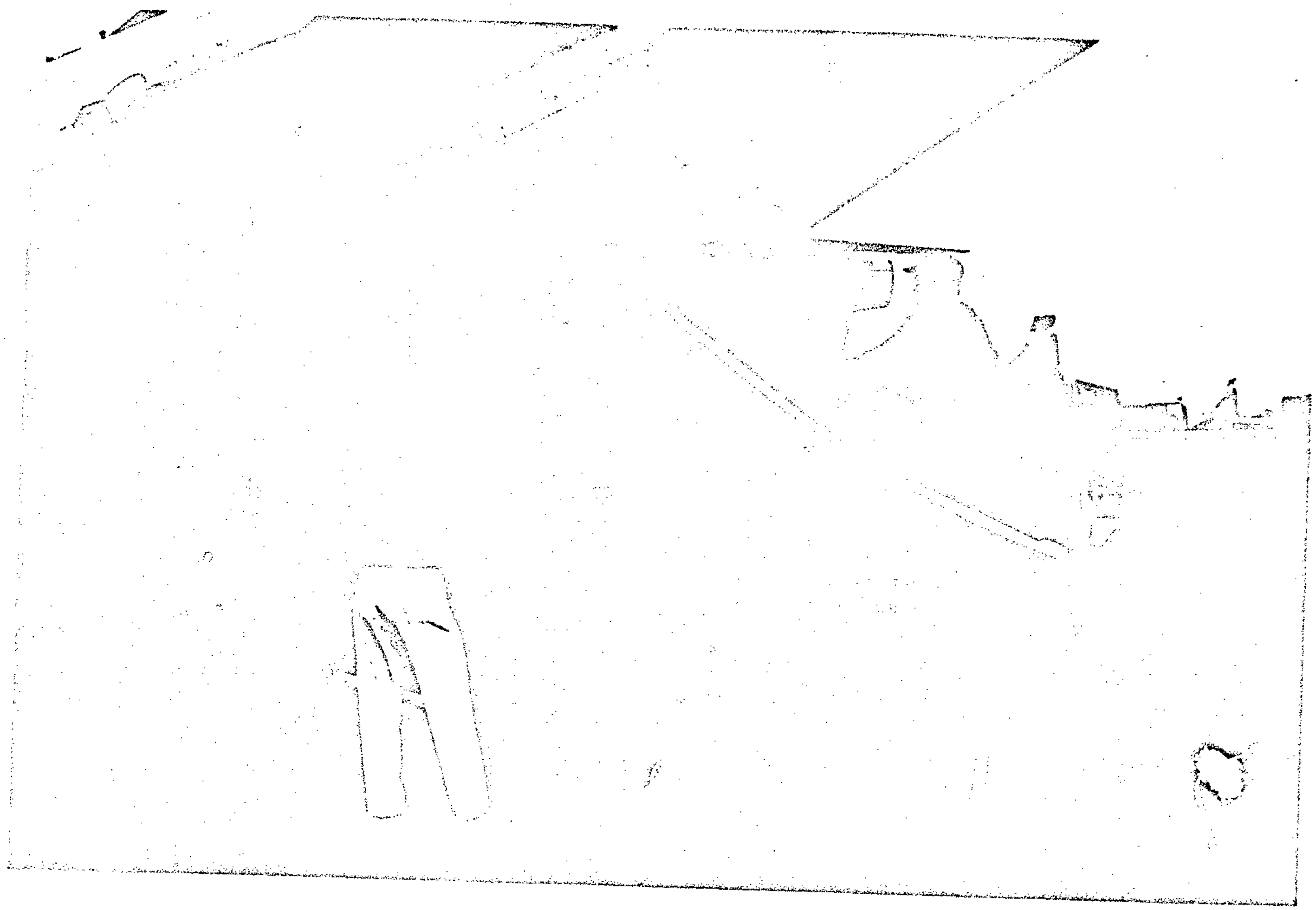

Figure 8. Maneuvering service module into C-123 cargo aircraft

ENVIRONMENTAL TESTING

Availability of resources in the Climatic Laboratory dictated the following order for MIL-STD-810B environmental testing:

Method No.	Test
502	Low temperature
501 - Procedure I	High temperature
510	Dust
507 - Procedure I	Humidity
506	Rain

FUNCTIONAL TEST. Before and after each environmental test, the following systems were functioned to insure proper operation:

- Door latches
- Door interlocks
- Disposal chutes
- Shower (water pump)
- Water heater
- Air heater
- Filter-blower unit
- Lights
- Dampers

During or following each environmental test, the modification kit was operated by test personnel for a specified number of cycles. Each cycle consisted of the following operations:

1. Enter service module through entrance airlock.
2. Operate one clothes disposal chute.
3. Operate shower for 1 to 2 minutes.
4. Leave service module through exit airlock.

The following data were recorded before, during, and after each cycle:

1. Differential pressure between each service module compartment and the test chamber in inches of water gage (IWG).

2. Temperature in each service module compartment and the test chamber in degrees Fahrenheit (°F).

3. Voltage (volts), current (amperes), and power (KW) requirements.

4. Shower water temperature in °F.

LOW TEMPERATURE TEST. The modification kit was subjected to a temperature of -[illegible]°F for 48 hours in a storage configuration. The temperature was raised to -25°F, and the modification kit was prepared for operation. The water storage tank was filled, and ten pass-through cycles were conducted as described in the functional test. The temperature was returned to ambient conditions (50° to 90°F), and ten more pass-through cycles were conducted.

HIGH TEMPERATURE TEST. The modification kit was subjected to a temperature of 160°F for 48 hours in a non-operating configuration. The temperature was lowered to 120°F, and ten pass-through cycles were conducted. The temperature was returned to ambient conditions, and ten more pass-through cycles were conducted.

DUST TEST. The modification kit was placed in the chamber in a non-operating configuration. The intake of the blower and the orifices on the building simulator were sealed prior to the test. The chamber temperature was adjusted to 73°F with a relative humidity of less than 22 percent. The air velocity was adjusted to 1,750 feet per minute (fpm), and 140-mesh silica flour was introduced into the chamber at a 0.3 gram per cubic foot (gram/ft³) of air concentration. These conditions were maintained for six hours. The dust feed was stopped, and the air velocity was reduced to 300 fpm. The chamber temperature was raised to 145°F, and the relative humidity was maintained at less than 10 percent. These conditions were maintained for 16 hours.

With the temperature held at 145°F, the air velocity and dust concentrations were adjusted to 1750 fpm and 0.3 gram/ft³, respectively. These conditions were maintained for six hours.

The wind and dust were turned off, and the modification kit was returned to ambient conditions, inspected, and operated for ten pass-through cycles.

HUMIDITY TEST. The modification kit was placed in the chamber in a non-operating configuration. The orifices in the building simulator were not sealed. The chamber temperature and relative humidity were gradually raised over a period of two hours to 160°F and 95 percent, respectively. These conditions were maintained for six hours. With the relative humidity maintained at 85 percent or greater, the chamber temperature was reduced to 82°F over a period of 16 hours. This constituted one cycle of 24 hours duration. This cycle was repeated 10 times for a period of 240 hours or 10 days. The modification kit was returned to ambient conditions and visually inspected. No pass-through cycles were conducted.

RAIN TEST. The modification kit was placed under the rain facility and put into operation. The rainfall rate was adjusted to five inches per hour (in./hr) and maintained for ten minutes. The rainfall rate was then increased to 12 in./hr and maintained for five minutes. The rate was reduced to 5 in./hr and maintained for 15 minutes. Five minutes after the initiation of the rain, the wind source was turned on, adjusted to 40 miles per hour (mph),

and maintained until five minutes before the end of the rain. Two pass-through cycles were conducted during the 5 in./hr rain, one with the 40 mph wind, and one after the wind source was turned off.

This test was repeated four times so that each side of the service module was subjected to the 40 mph wind. Ten pass-through cycles were conducted at the end of the test.

SIMULANT TESTING

FILTER CHALLENGE. Before simulant testing of the modification kit was attempted, the three filter-blower units were challenged using the biological simulant Bacillus globigii (BG) and the chemical simulant Methyl Acetoacetate (MAA). At least two BG challenges and two MAA challenges were conducted using each filter unit. Each simulant was injected directly into the intake of the blower, and samples were collected at the exhaust of the filter.

BIOLOGICAL SIMULANT TESTING. Two biological simulant challenges were conducted. Before testing began, the modification kit was functioned to insure proper operation of all systems. Twenty-five areas were marked off on the inside and outside of the modification kit, decontaminated, and sampled with swabs. The simulant, BG, was disseminated inside the inflatable shelter to obtain an aerosol cloud of approximately 1×10^6 viable cells per cubic meter (cells/m^3). A more complete description of these procedures is contained in Appendix I.

During the first biological simulant challenge, the modification kit was operated for a one-hour holding period with no entries or exits conducted. Samplers at all stations, both inside and outside the modification kit, were aspirated for five minutes at 20-minute intervals. At the end of the holding period, all samplers were changed.

Before the first pass-through cycle, samplers at all stations were aspirated for five minutes to obtain a background reading. A test subject wearing an M-3 CB protective suit and an M-17 protective mask functioned the modification kit during the pass-through cycles. During the first biological challenge, a pass-through cycle consisted of the following:

1. Sampler in entrance airlock was aspirated for five minutes. Test subject entered entrance airlock after sampling was initiated and waited until sampler stopped.

2. When sampler in entrance airlock stopped, samplers in undressing room, dressing room, and outside modification kit were aspirated for five minutes. Test subject entered undressing room, brushed off suit, and operated clothes disposal chute.

3. Test subject took shower while wearing suit and mask, then waited in dressing room until samplers stopped.

4. When samplers in dressing and undressing room stopped, sampler in exit airlock was aspirated for five minutes. Test subject entered exit airlock and waited for sampler to stop. He then exited the modification kit.

5. After test subject exited modification kit, all samplers were aspirated for five minutes to determine presence of contamination and as a background for the second cycle.

After the second cycle was completed, all samplers were changed and the series repeated. Six pass-through cycles were conducted. At the end of the test, swab samples were taken at the 25 areas swabbed before the test. Temperature and differential pressure were monitored during the test in the same manner as during the environmental tests.

The second biological challenge was conducted in the same manner as the first with the following exceptions:

1. The holding period was two hours long with five-minute samples taken every 20 minutes.

2. The timer on the WAIT-ENTER lights was set for 10 seconds, and the sampler in the entrance airlock was aspirated for 30 seconds. After the sampler was turned on, the test subject entered the airlock, and when the light flashed from WAIT to ENTER, he entered the undressing room. When the sampler in the undressing room was turned on, he continued with the cycle as during the first test.

Eight cycles were conducted during the second biological simulant challenge.

CHEMICAL SIMULANT TESTING. Two chemical simulant challenges were conducted. Prior to introduction of MAA into the inflatable shelter, samplers were aspirated in the test area to obtain a background reading as required by MAA assay procedures (see Appendix II). The modification kit was functioned to insure proper operation of all systems, and swab samples were taken at the 25 marked areas which had been decontaminated. The chemical simulant MAA was disseminated into the inflatable shelter to obtain an aerosol concentration of approximately 100 grams per cubic meter (gm/m^3). Prior to pass-through cycles, the modification kit was subjected to a holding period in the same manner as during the biological challenges. Pass-through cycles were conducted in the same manner as during the second biological challenge. Samplers from the stations outside the modification kit were operated during the test, and additional simulant was disseminated to maintain a satisfactory concentration in the inflatable shelter. At the conclusion of the test, swab samples were taken at the 25 marked areas.

During the first chemical simulant challenge the holding period was two hours long and six pass-through cycles were conducted. Swab samples were not taken during the second challenge due to the results of the first challenge, and the holding period was deleted due to a shortage of simulant. Seven pass-through cycles were conducted during the second chemical challenge.

HUMAN FACTORS

A human factors evaluation was conducted on the modification kit during testing to recommend possible improvements to the man/machine interface. This study is included as Appendix III.

SECTION V

TEST RESULTS AND DISCUSSION

CARGO FIT TESTING

The CB Modification Kit for Structures was loaded on a C-123 aircraft with 463L handling equipment. The parachute static lines were partially removed and swung out of the way in order to load the modification kit.

When being maneuvered into the cargo hatch, the service module cleared the upper cargo door by 2 inches. When mounted on conveyors and pallet, the service module cleared the aircraft ceiling by 7 inches and cleared the wheel wells by 9 inches on each side. The minimum clearance specified in T.O. 1C-123B-9, Technical Manual, Cargo Aircraft Loading and Unloading, is 6 inches on each side.

The weight and balance of the aircraft could not be computed because the center of gravity and weight data were not stenciled on the units as required for air-transportable items.

The three filter-blower units were loaded behind the service module (one on the floor and two on the ramp) so they would be jettisonable (Figure 4). The service module is not air-jettisonable.

The slots in the skids of the filter-blower units are too small and close together to facilitate forklift handling.

The loadmaster personnel performing the cargo fit test inspected the tie-down fittings provided and found them adequate.

ENVIRONMENTAL TESTING

The CB Modification Kit for Structures passed the low temperature, high temperature, dust, and rain tests, but failed the humidity test.

LOW TEMPERATURE TEST. Although several problems were encountered in preparing the modification kit for operation at -25°F after the 48-hour soak at -65°F, they were not considered major and were mainly concerned with features already programmed for changes. The flexible ducting was stiff and had to be heated before it could be attached to the flanges on the filter-blower unit and the influent air panel. The blower fan had to be turned by hand before it would run. Although the water system had been drained, a small [illegible] of water remained in the pump and had to be thawed with a space heater before the pump would function. When the shower was first operated, the drain pipe froze and had to be thawed with a space heater. During the pass-through cycles the shower was operated often enough to keep the pipe from [illegible].

The electrical strip heaters for heating incoming air were inadequate. The intake air delivered from the filter-blower unit remained at -19°F throughout the low temperature functional test. The chamber temperature was stabilized between 10°F and 20°F when the shower was not in operation (Table I).

Operating the shower produced clouds of water vapor and heated the service module. Air temperatures in the dressing and undressing rooms varied between 30°F and 40°F. Floor temperatures, excluding the shower stall floor, reached a maximum of 30°F. Shower water temperature was varied between 66°F and 120°F during the test. The average differential pressures recorded during the test are given in Table II.

HIGH TEMPERATURE TEST. No special problems were encountered during the high temperature test. All systems operated satisfactorily. The average temperatures recorded during the pass-through cycles are given in Table I. The average differential pressures recorded are given in Table II.

DUST TEST. The silica dust did not penetrate the service module. When the filter-blower unit was first turned on, the circuit breaker kicked out. When the switch was turned on a second time, the filter-blower unit functioned satisfactorily. All modification kit systems functioned satisfactorily during the pass-through cycles. The average temperatures recorded are contained in Table I. The average differential pressures are contained in Table II.

Table I. Internal temperature data during specified tests

	Temperature (°F)		
	Low temperature test	High temperature test	Dust test
Entrance airlock air	16-20 *	114	97
Undressing room air	10-30 *	110	95
Undressing room floor	2-30 *	100	87
Shower floor	27-90 *	100-115 *	85-100*
Water storage	66	87	95
Dressing room floor	12-20 *	96-109 *	82
Dressing room air	15-40 *	109	96
Intake air from filter-blower	-19	104-110	94
Exit airlock air	5-15 *	114	97
Chamber air	-22	120	93

*Temperature varied due to shower operation.

Table II. Differential pressures during specified tests

	Pressure (Inches of water gage)*			
	Plenum chamber	Exit airlock	Entrance airlock	Dressing room
Low Temperature Test				
Entrance airlock open	0.49	0.37	0	0.51
Static	0.55	0.56	0.54	0.55
Exit airlock open	0.5	0	0.48	0.52
High Temperature Test				
Entrance airlock open	0.45	0.48	0	0.45
Static	0.59	0.61	0.58	0.59
Exit airlock open	0.41	0	0.42	0.43
Dust Test				
Entrance airlock open	0.49	0.50	0	0.47
Static	0.58	0.60	0.56	0.57
Exit airlock open	0.44	0	0.43	0.44

*Design conditions are 0.4 to 0.6 IWG.

HUMIDITY TEST. The humidity test severely degraded the modification kit. Although all fittings were military specification items, uncoated steel screws, latches, and fittings were severely corroded. Those fittings which had a chromate dip were unaffected. The plunger-type door releases on the inside of the outer airlock doors had to be broken loose with a hammer before they would function (Figure 9). The switches on the door jams of the outer airlock doors, which control the dampers, were frozen. This means that the modification kit would lose overpressure whenever an airlock door was opened. This switch also controls the WAIT-ENTER lights in the entrance airlock. The floor in the shower was buckled upward so that the side panels could not be opened, precluding use of the shower (Figure 10). The interior airlock doors had swelled and were cracked. Air heater control relays located in the electrical control panel were corroded (Figure 11). The gasket on the [illegible] box containing the control panel was loose. The floor in the plenum chamber was buckled slightly so that the perforated door could not be opened (Figure 12). Further inspection revealed that the swelling and buckling were due to expansion of the polyurethane foam insulation (Figure 13 and 14). Paint on the ceiling had blistered (Figure 15).

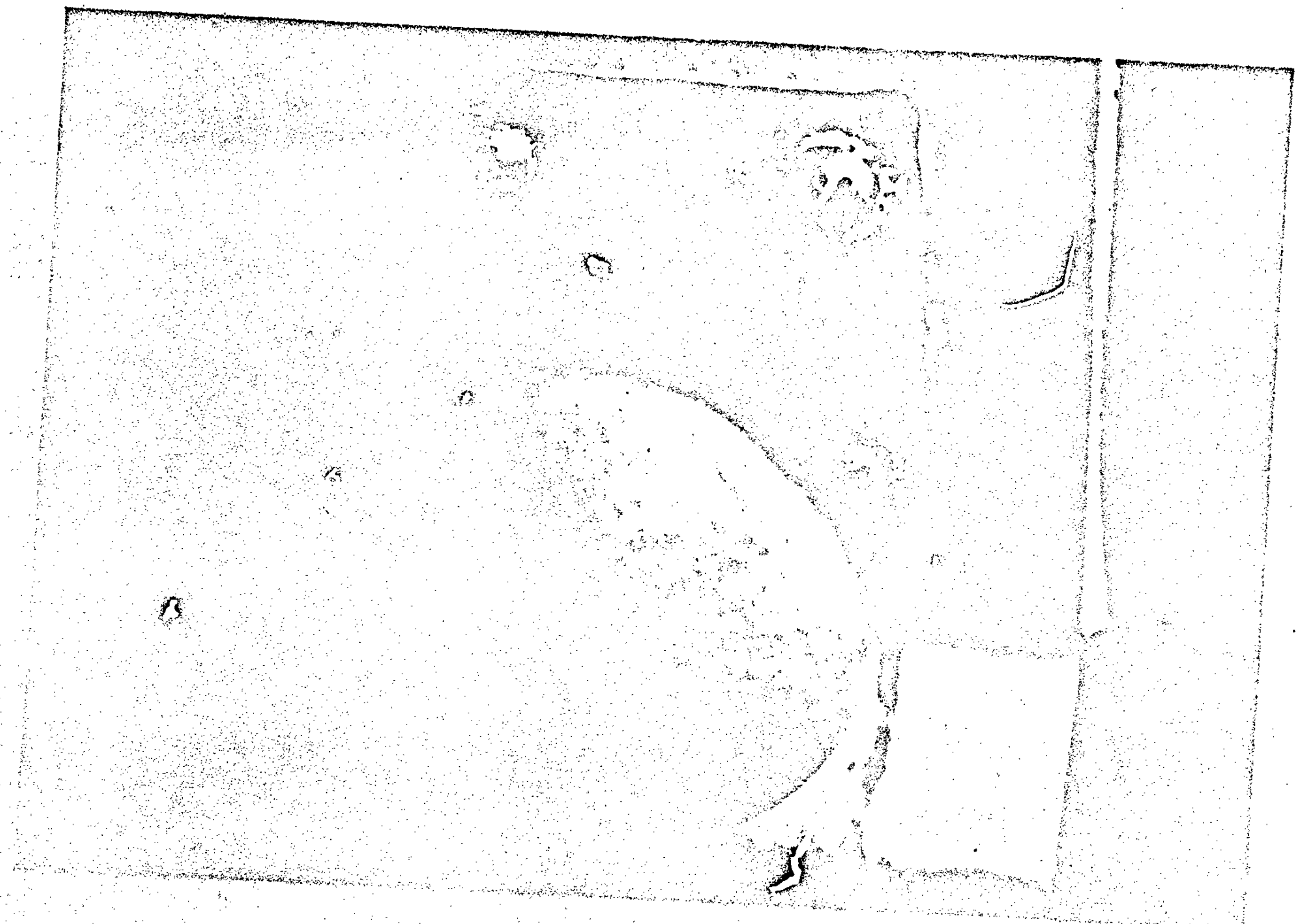

Figure 9. Corroded outer airlock door release plunger after humidity test

Figure 10. Buckled shower stall floor after humidity test

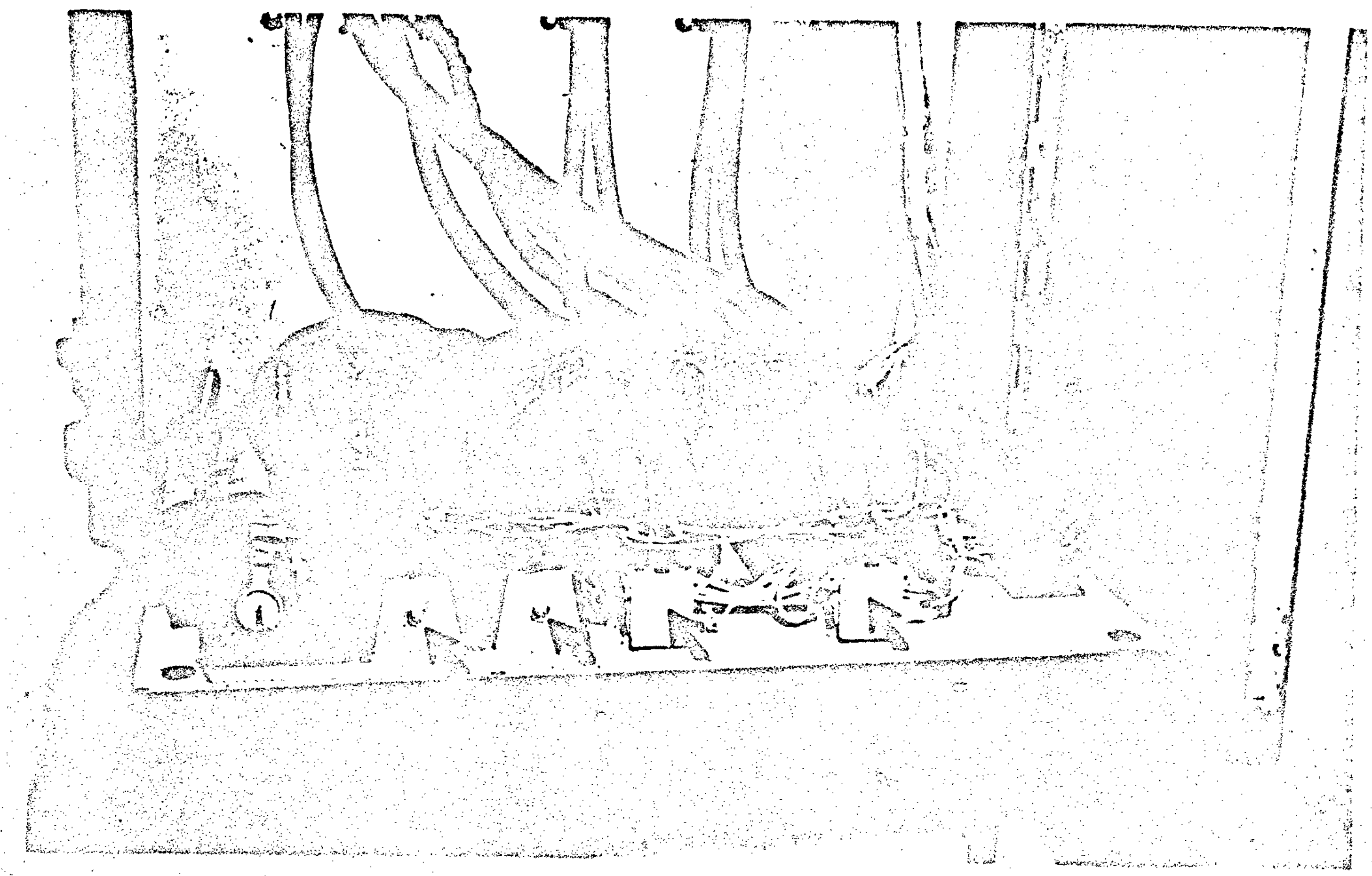

Figure 11. Back of electrical control panel showing corroded air heater system relays after humidity test

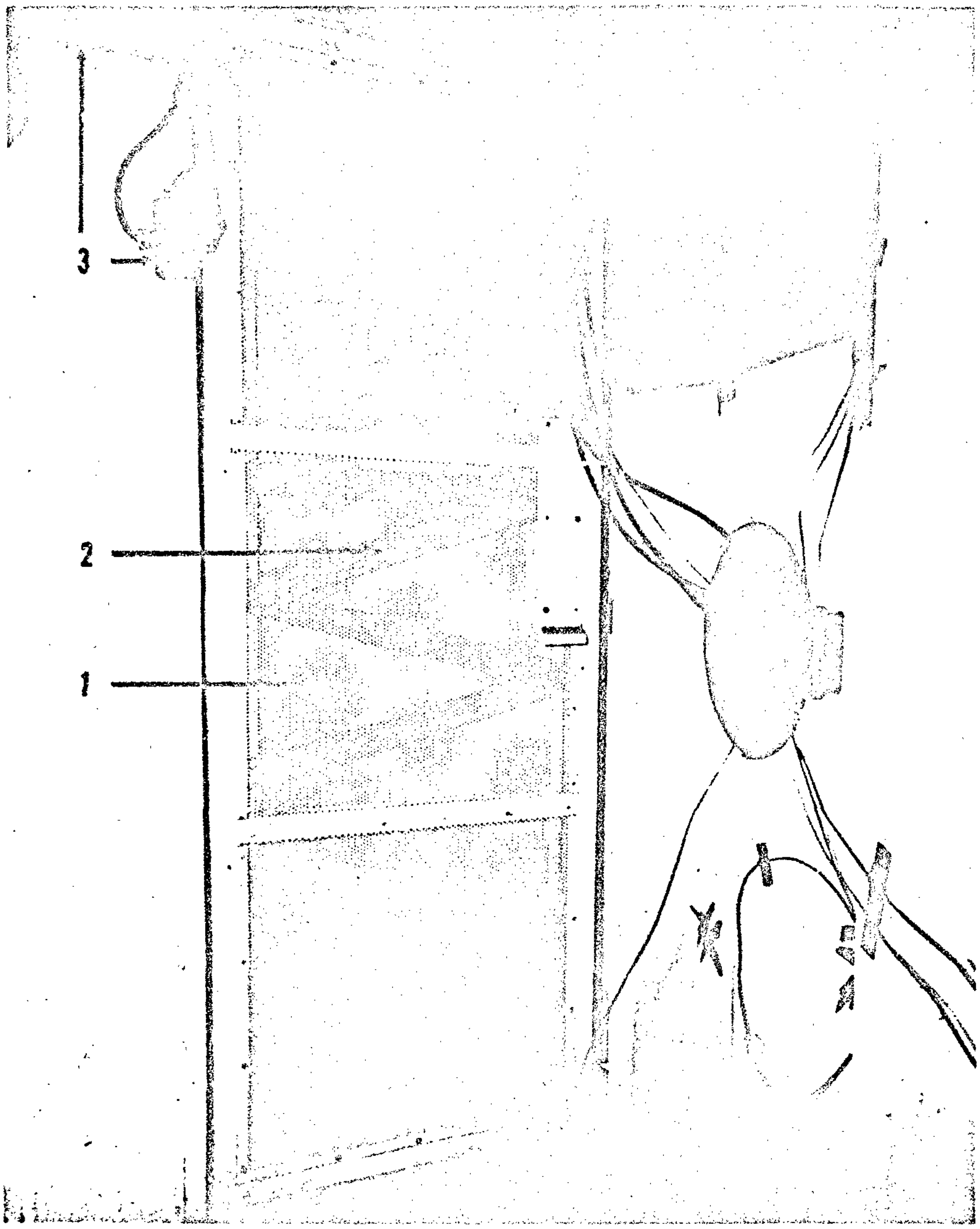

Figure 12. Service module dressing room after humidity test: (1) perforated door at maximum opening, (2) electrical strip heaters, and (3) corroded fittings

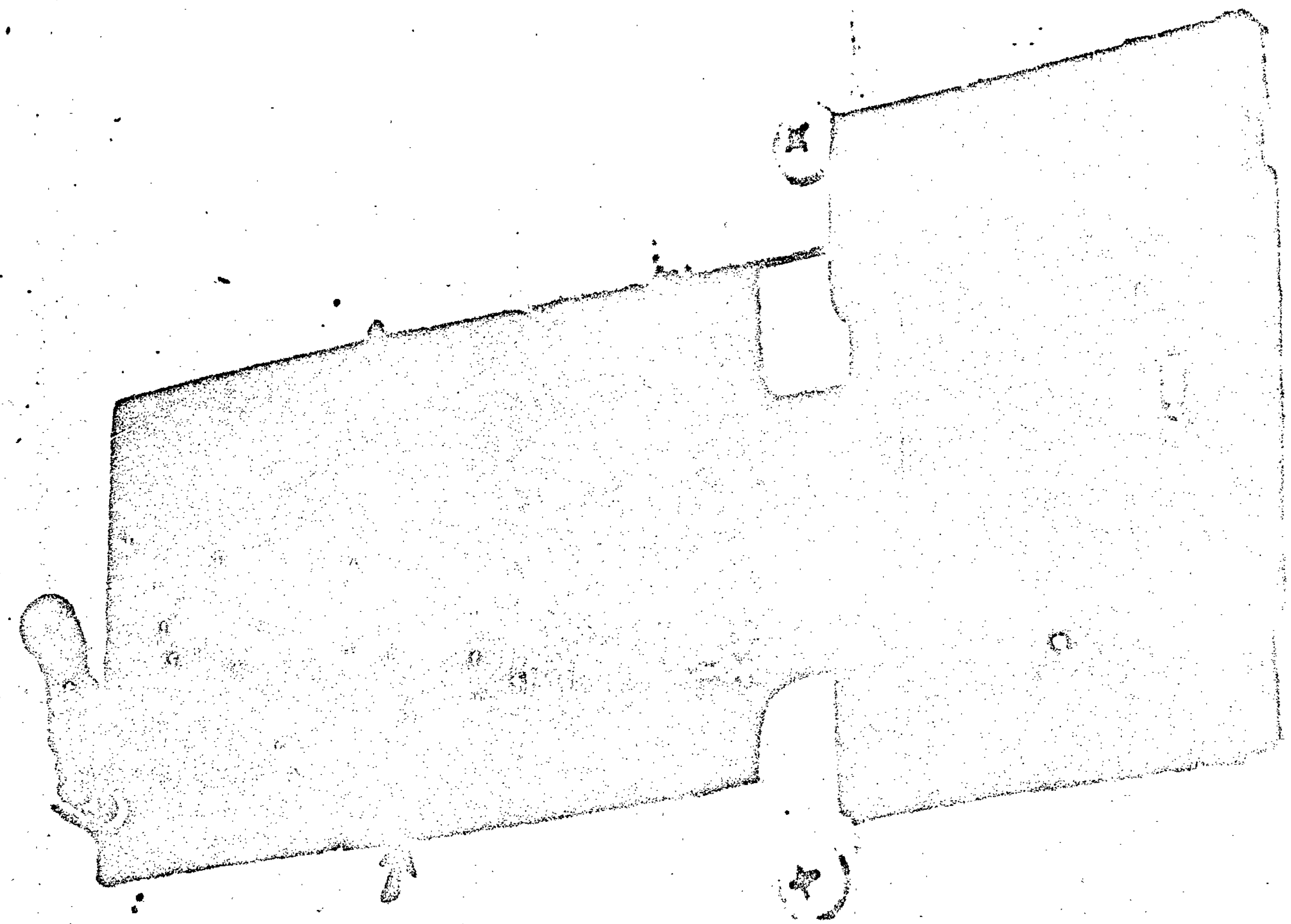

Figure 13. Polyurethane foam swelled from humidity test

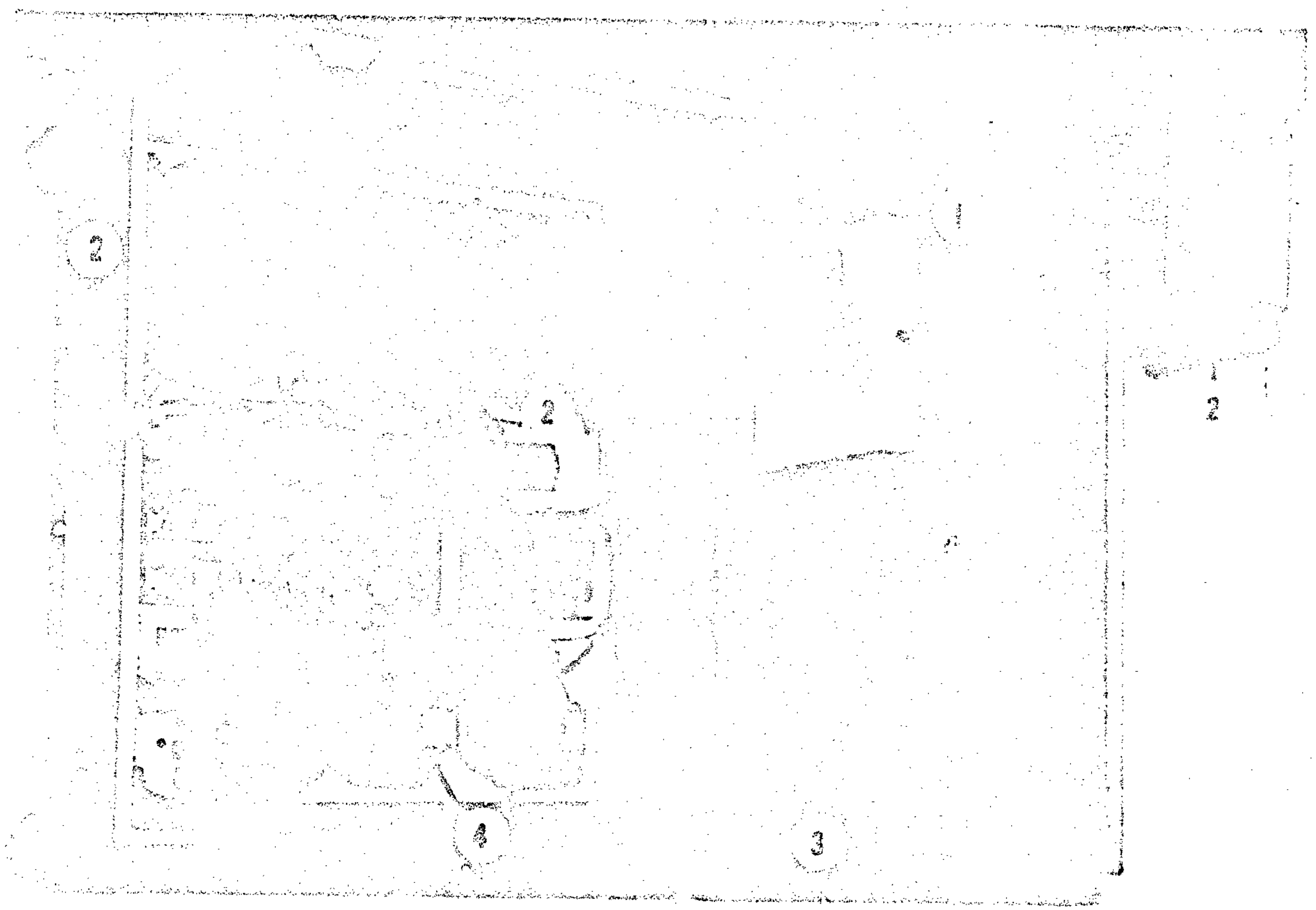

Figure 14. Junction box in service compartment after humidity test: (1) loose gasket, (2) corrosion, (3) swelled polyurethane foam, and (4) time delay relays

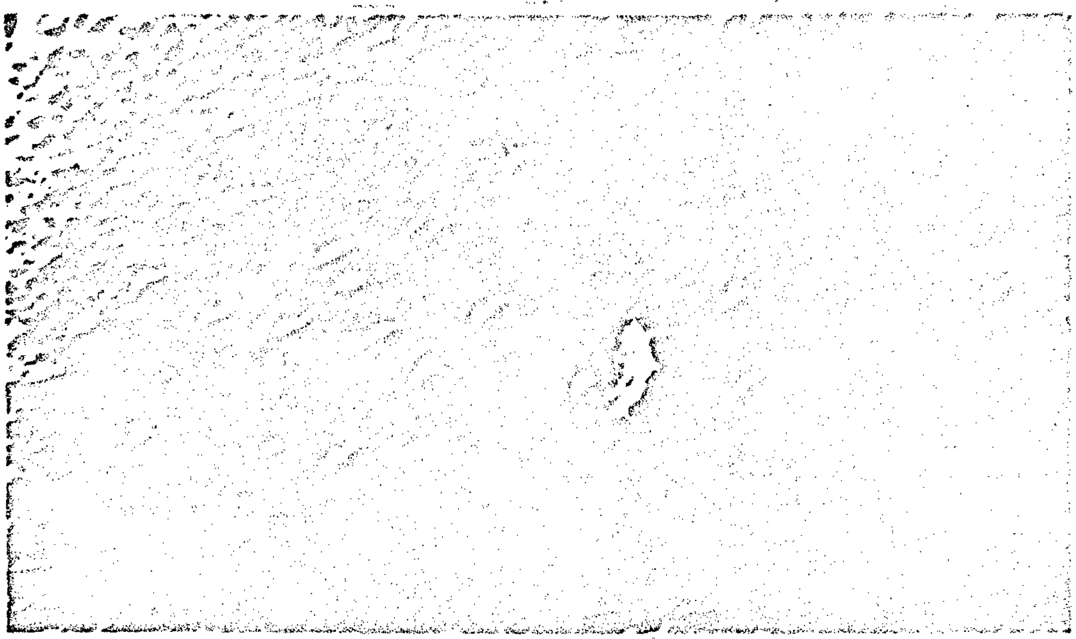

Figure 15. Paint on ceiling of service module blistered from humidity test

The water pump, the blower, and the lights still functioned. No attempt was made to function the water heater or the air heater. After a two-week period, the buckling in the plenum chamber floor had gone down so that the perforated door could be opened. Testing on this unit was terminated, and the rain test was conducted on the other unit after completion of simulant testing.

RAIN TEST. All modification kit systems functioned satisfactorily during the rain test. Satisfactory overpressure (Table III) was maintained during a 12-in./hr rain while a 40-mph wind was directed at each side of the service module. Rainwater running down the side of the service module entered the airlocks via a lip on the top of the outer doors.

Modification kit power consumption was measured during testing at 10 kw maximum and distributed as follows:

Lights and blower	2 kw
Water heater	4.5 kw
Air heaters	3.5 kw

Table III. Differential pressures: Rain Test

	Pressure under Wind/No Wind Conditions (inches of water gage)			
	Blower chamber	Exit airlock	Entrance airlock	Dressing room
Front*				
Entrance airlock open	0.5/0.5	0.5/0.5	0.1/0	0.48/0.52
Static	0.55/0.5	0.6/0.5	0.54/0.46	0.56/0.52
Exit airlock open	0.48/0.48	0/0	0.54/0.42	0.54/0.52
Blank End*				
Entrance airlock open	0.5/0.5	0.5/0.5	0/0.03	0.52/0.50
Static	0.5/0.5	0.5/0.5	0.42/0.45	0.51/0.52
Exit airlock open	0.5/0.5	0/0.01	0.4/0.41	0.44/0.49
Back*				
Entrance airlock open	0.7/0.55	0.6/0.5	0/0	0.65/0.54
Static	0.7/0.55	0.6/0.55	0.6/0.51	0.7/0.58
Exit airlock open	0.5/0.55	0/0	0.42/0.44	0.66/0.52
Blower End*				
Entrance airlock open	0.5/0.55	0.5/0.5	0/0	0.52/0.56
Static	0.55/0.65	0.48/0.55	0.47/0.53	0.5/0.60
Exit airlock open	0.45/0.55	0/0	0.4/0.44	0.52/0.52

*See Figure 4.

SIMULANT TESTING

FILTER CHALLENGES. Eight biological filter challenges were conducted on the three filter-blower units (Table IV).

Filter efficiency was calculated, assuming the design flow rate of (60 [illegible]) through the filter-blower unit and 12.5 liters per minute through the [illegible]. The average filter efficiency of the filter-blower unit [illegible]

used for simulant testing was 99.99 percent. The filter's military specification (MIL-F-51215A) requires a minimum efficiency of 99.97 percent.

Six chemical filter challenges were conducted on the three filter-blower units. Assuming a 600-cfm flow rate through the filter, MAA was disseminated at the intake of the blower at a 76.5 milligrams per cubic meter (mg/m^3) of air concentration. Results of each challenge, when compared to background readings, indicated that no detectable quantities of MAA passed through the filter.

The sampling and assay techniques used are capable of detecting MAA in quantities equivalent to 0.2 mg/m^3 of air. The calculated filter efficiency was greater than 99.7 percent.

BIOLOGICAL SIMULANT TESTING. The efficiency (99.99 percent) of the modification kit was calculated from data obtained during the biological simulant challenges. (See Table V.) Complete data from the simulant challenges are presented in Appendix I. The filter efficiency limits the maximum efficiency obtainable for the modification kit. Since both the filter and modification kit efficiencies exceeded the design requirements of the filter (99.97 percent), the modification kit passed the biological simulant challenge.

Biological Simulant Challenge No. 1. Test subjects performing the pass-through cycles remained in the entrance airlock for 5 minutes when entering the service module. The airlock purged completely during this time. Samples taken in the undressing and dressing rooms during the pass-through cycles showed no increase over background samples taken between cycles. The system efficiency calculated from background readings between cycles was comparable to results obtained during the filter challenges. Simulant contamination did not build up within the service module during the test.

Swab samples indicated contamination was restricted to the airlocks and exterior of the service module. Only one cell was discovered in the interior of the service module (on dressing room wall).

Biological Simulant Challenge No. 2. During the holding period, the simulant concentration inside the service module was higher than the average of background samples taken between pass-through cycles during the rest of the test. The cause of this was not determined. Background samples taken between cycles were comparable to those of the first simulant challenge.

The higher simulant concentration recorded in the entrance airlock was due to the shorter sampling time (30 seconds). Waiting time in the entrance airlock was reduced to ten seconds in order to obtain more realistic interior contamination data. Shortening the time resulted in some contamination reaching the interior of the service module through the airlock. The simulant concentration in the undressing room was approximately twice that in the dressing room. However, there was still no buildup of contamination during the course of the test. Between cycles the interior concentration returned to a level equivalent to that obtained during the filter challenges.

Table IV. Results of biological filter challenges

	Filter-blower unit serial number							
	6	6	6	6	7	7	8	8
Total cells (BG) aerosolized at intake in 10 minutes	1.5×10^8	1.86×10^9	1.95×10^8	2.09×10^9	1.65×10^8	1.49×10^9	1.79×10^8	1.78×10^9
Total cells collected in 10 minutes	62	31	0	0	7	0	1	32
Calculated filter slippage in 10 minutes (cells)	8.33×10^4	4.17×10^4	0	0	9.41×10^3	0	1.34×10^3	4.30×10^4
Efficiency (percent) $\left(1-\frac{\text{filter slippage}}{\text{total cells}}\right) \times 100$	99.944	99.9978	100	100	99.9943	100	99.99925	99.9976

Table V. Results of biological simulant challenges

	Challenge no. 1	Challenge no. 2
Average aerosol concentration during pass-throughs $\left(\frac{\text{cells}}{\text{m}^3}\right)$	3.46×10^5	5.97×10^5
Average service module interior concentration between pass-throughs $\left(\frac{\text{cells}}{\text{m}^3}\right)$	22	32.4
Average entrance airlock concentration (occupied) $\left(\frac{\text{cells}}{\text{m}^3}\right)$	9.5×10^3	4.11×10^4*
Average undressing room concentration (occupied) $\left(\frac{\text{cells}}{\text{m}^3}\right)$	**	5.45×10^2
Average dressing room concentration (occupied) $\left(\frac{\text{cells}}{\text{m}^3}\right)$	**	2.64×10^2
System efficiency (percent) $1 - \left(\frac{\text{Interior Concentration}}{\text{Aerosol Concentration}}\right) \times 100$	99.99364	99.99456

*[illegible]-second sample
**Not greater than static level

Swab samples indicated contamination on the outside of the service module, in the entrance airlock, and in the shower stall (4 cells).

CHEMICAL SIMULANT TESTING. The results of the two chemical simulant challenges are summarized in Table VI. Complete data from the simulant challenges are presented in Appendix II. Pass-through cycles were conducted in the same manner as during the second biological simulant challenge. The simulant concentration in the shelter could not be held constant due to a shortage of simulant and fast dissipation of the simulant cloud.

Chemical Simulant Challenge No. 1. During the first chemical simulant challenge, no contamination was found in the undressing room or dressing room. The entrance airlock purged satisfactorily, but slight contamination (0.2 - 0.5 mg/m^3) was recorded in the exit airlock. Swab samples were taken, but the results were inconclusive due to the presence of other chemicals. For this reason swab samples were deleted in the second challenge.

Chemical Simulant Challenge No. 2. During the second chemical simulant challenge slight contamination was recorded in the undressing room on three occasions (1.1, 0.6, and 0.4 mg/m^3). Two of these samples were taken between cycles when previous data indicated that the airflow would have had time to purge the area. Contamination of the impingers during handling or assay is the suspected cause. No contamination was found in the dressing room. The airlocks purged satisfactorily.

The majority of impingers contained no detectable contamination, giving an efficiency comparable to that obtained during the filter challenge. The accuracy of the modification kit's calculated system efficiency was limited by the minimum quantity of MAA detectable (0.2 mg/m^3) using the assay procedures in Appendix II. Analysis of the data indicated that the modification kit passed the chemical simulant challenge.

During the process of testing, several minor mechanical deficiencies became apparent. There is a fitting on the front of the service module where a garden hose is attached to fill the water storage tank. This is a fixed female fitting, and the garden hose must be screwed into it by twisting the entire hose.

The lift rings around the top of the service module were used during the cargo fit test and during moving operations. The capacity of the anchor points of the lift rings is marginal. While they did not pull out, they did become loose.

By the end of testing, the handles on the inside of the interior airlocks had become loose from repeated use.

The interlock latches originally had two-channel catches on the doors. These could not be aligned with the interlocks on the door jambs. The top channel was filed down (Figure 16), and alignment was accomplished.

Table VI. Results of chemical simulant challenges

	Challenge no. 1	Challenge no. 2
Average aerosol concentration during pass-throughs (mg/m^3)	57.4	52
Service module interior concentration between pass-throughs (mg/m^3)	<0.2	<0.2
System Efficiency $\left(1-\frac{\text{Interior concentration}}{\text{Aerosol concentration}}\right) \times 100$ (percent)	>99.65	>99.62
Average entrance airlock concentration (occupied) (mg/m^3)	10.18	11.1
Average undressing room concentration (occupied) (mg/m^3)	<0.2	<0.2
Average dressing room concentration (occupied) (mg/m^3)	<0.2	<0.2

Figure 16. Interlock catch on inner airlock door with top channel filed off.

By the end of active testing the interlocks were faulty. They are too fragile for continuous use. The catch pictured (Figure 16) would not maintain alignment, and the interlock had to be bypassed.

The shower nozzle in modification kit no. 2 (used for simulant testing) was either broken or designed improperly. The pump did not provide enough pressure to make it function properly. A spacer had to be inserted in the nozzle so that water would spray rather than pour from it.

HUMAN FACTORS EVALUATION

A human factors evaluation of the CB Modification Kit for Structures was conducted by the Human Factors/Biomedical Division (ADHZ) and is included as Appendix III. The following deficiencies were noted during the human factors evaluation.

1. The air heating system in the modification kit is inadequate for operating environments down to -25°F.

2. The timers for the WAIT and ENTER lights (Figure 14) had to be adjusted by trial and error since they were not labeled as to specific function or scaled for adjustment.

3. Upon entering the service module for the first time, test subjects became confused about the operation of the inner airlock door. Although there is a handle on the door which may be pulled, the door is opened by pushing. This handle is necessary to insure proper operation of the interlock system, but the door should be labeled PUSH TO OPEN.

4. The shower temperature control knob was not labeled, necessitating adjustment of the water temperature by trial and error.

SECTION VI

CONCLUSIONS

1. The CB Modification Kit for Structures tested met the requirements of MIL-STD-810B, dated 15 June 1967, for high temperature, low temperature, dust, and rain.

2. The CB Modification Kit for Structures failed humidity testing under MIL-STD-810B due to floor buckling and corrosion.

3. The CB Modification Kit for Structures meet design requirements and will protect personnel with 99.6 percent efficiency in chemical simulant (Methyl Acetoacetate) concentrations up to 100 mg/m^3 and with 99.99 percent efficiency in biological simulant (Bacillus globigii) concentrations up to 10^8 cells/m^3.

4. The air heating system in the CB Modification Kit was inadequate.

5. Controls in the CB Modification Kits were not all labeled properly or positioned for efficient use.

6. Testing revealed design deficiencies in the interlock door handles, lift rings, and the shower nozzle.

7. The CB Modification Kit for Structures will fit on a C-123 aircraft with sufficient clearance to satisfy air transportability requirements.

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APPENDIX I

BIOLOGICAL SIMULANT TESTING OF THE CB MODIFICATION KIT FOR STRUCTURES

INTRODUCTION

The CB Modification kit for Structures was challenged with the biological agent simulant Bacillus globigii (BG). Two separate challenges were conducted in a BG aerosol of approximately 1×10^6 viable cells/m^3. The modification kit was allowed to operate in the simulant cloud for a period of 1 to 2 hours before pass-through cycles were conducted.

DESSEMINATION

The "C" generator, containing one liter of 60×10^5 viable cells/ml, slurry was placed midway the end curtain and was activated until empty. Two De Vilbiss no. 841 nebulizers, containing 300 ml each of 150×10^6 viable cells/ml slurry, were set to deliver 0.2 ml/min. The nebulizer and "C" generator slurries were made from a heat-shocked BG slurry with a viability of 125×10^8 viable cells/ml. Each nebulizer was placed in front of a fan on opposite sides of the CB modification kit, and the fans were blowing in opposite directions.

The aerosol cloud was generated by first turning on the fans (high speed), then each nebulizer. The "C" generator was activated from outside the shelter immediately after turning on the nebulizers. Sampling began one minute after the "C" generator was emptied.

SAMPLING

All aerosol samples were taken with 12.5 liter/minute all-glass impinger samplers with plastic uncoated pre-impingers attached. Unless otherwise stated, all samplers were aspirated for five minutes. (See Figure I-1 for sampler locations.)

Aerosol samplers are identified as follows: Example: III C-4

1. The Roman numeral (III) designates the cycle during which the sample was taken.

2. The letter (C) designates the sampling station.

3. The number (4) designates the sampling position on the vacuum manifold.

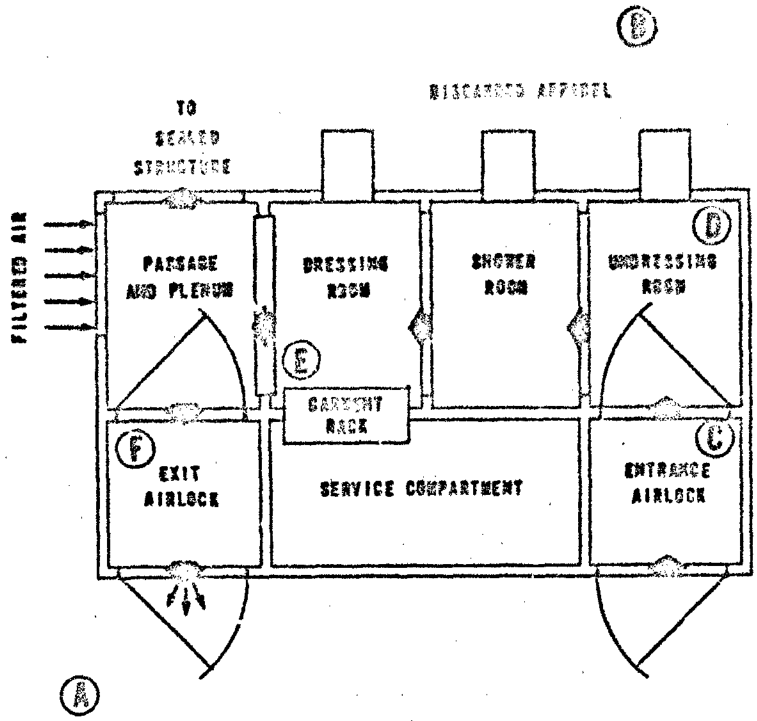

Figure I-1. Sampling stations

Swab samples were taken from marked 3-inch by 3-inch areas with sterile cotton swabs. (See Table I-1 for location of marked areas.) Pre-mission swab samples were taken after the marked areas had been decontaminated with 15 percent hydrogen peroxide and allowed to dry. At the completion of the challenge, the areas were swabbed again.

Table I-1. Location of swab sampling areas on Service Module of CB Modification Kit

Sampling area	Location
	Inside Service Module
1	Entrance airlock, upper right-hand wall
2	Entrance airlock, lower left-hand wall
3	Entrance airlock, inner door
4	Undressing room, upper right-hand wall (when facing contaminated apparel outlet)
5	Ceiling
6	Undressing room, directly left of contaminated apparel outlet
7	Shower stall, directly beneath shower knob
8	Shower stall, directly left of mask outlet
9	Dressing room, directly left of towel outlet
10	Dressing room, inside door of control panel
11	Dressing room, front of water heater
12	Dressing room, upper rear wall above water storage tank
13	Dressing room, left of perforated door
14	Plenum chamber, ceiling
15	Plenum chamber, exit door
16	Plenum chamber, on wall at lower left-hand side of exit door
17	Exit airlock, center right-hand wall
18	Exit airlock, inner door
19	Exit airlock, center left-hand wall
20	Exit airlock, outer door near exhaust port
	Outside Service Module
21	Right-hand side of exit door
22	Left-hand side of entrance door
23	Directly right of contaminated apparel outlet
24	Left of towel outlet
25	Right center of panel next to influent air panel

BIOLOGICAL SIMULANT CHALLENGE NO. 1: MISSION 2063, 4 March 1969.

1. Pre-mission swab samples taken at 25 predetermined points
2. Dissemination (4 1/2 hours)

   Nebulizer no. 1 disseminated 50 ml of slurry at the rate of 0.18 ml/min.

Nebulizer no. 2 disseminated 65 ml of slurry at the rate of 0.24 ml/min

The "C" generator disseminated one liter of test agent slurry

3. Holding Period. No one entered the modification kit during this time. Sampling was initiated one minute after dissemination was begun.

Samplers were aspirated according to the following outline:

Time (in minutes)	Samplers operated
0-5	A-1, B-1, C-1, D-1, E-1, F-1
25-30	A-2, B-2, C-2, D-2, E-2, F-2
50-55	A-3, B-3, C-3, D-3, E-3, F-3

(For results see Table I-2.)

4. Pass-Through Cycles. After the holding period was completed, six pass-through cycles were conducted. Impingers were changed after every second cycle. Samplers were aspirated according to the following outline:

a.

Time (in minutes)	Operation
0 - 5	Samplers IA-1, IB-1, IC-1, ID-1, IE-1, and IF-1 pulled (background).
5 - 10	Sampler IC-2 pulled. Volunteer entered chamber C and remained until impinger IC-2 stopped.
10 - 15	Samplers IA-2, IB-2, ID-2 and IE-2 pulled. Volunteer entered chamber D, and simulated de-suit. Volunteer took 2-minute shower; then progressed to chamber F when impinger IE-2 stopped.
15 - 20	Sampler IF-2 pulled. Volunteer exited chamber F when impinger IF-2 stopped.

(Clock stopped for 30 seconds while volunteer exited shelter)

20 - 25	Samplers I-11A-3, I-11B-3, I-11C-3, I-11D-3, I-11E-3, and I-11F-3 pulled (post-cycle background for pass-through I and pre-cycle background for pass-through II).

Time (in minutes)	Operation
25 - 30	Sampler IIC-4 pulled. Volunteer entered chamber C and remained until impinger IIC-4 stopped.
30 - 35	Samplers IIA-4, IIB-4, IID-4 and IIE-4 pulled. Volunteer entered chamber D and simulated de-suit. Volunteer took 2-minute shower; then progressed to chamber F when impinger IIE-4 stopped.
35 - 40	Sampler IIF-4 pulled. Volunteer exited chamber F when impinger IIF-4 stopped.

(Clock stopped for 30 seconds while volunteer exited shelter.)

40 - 45	Samplers IIA-5, IIB-5, IIC-5, IID-5, IIE-5, and IIF-5 pulled (post-cycle background for pass-through II).

b. Pass-through cycles I and II completed.

c. Impingers for cycles I and II were replaced by impingers for next two cycles.

d. Test continued until six pass-through cycles were completed. (For results, see Table I-2.)

e. Post-mission swabs were taken. (For results, see Table I-3.)

Table I-2. Aerosol cloud and service module interior concentration data: challenge no. 1

Sampler identification	Total cells per impinger	Cells per cubic meter of air
A-1	1.56×10^5	2.50×10^6
A-2	6.20×10^4	1.00×10^6
A-3	2.75×10^4	4.40×10^5
B-1	1.61×10^5	2.57×10^6
B-2	5.88×10^4	9.40×10^5
B-3	3.43×10^4	5.48×10^5
C-1	6	9.6×10^1
C-2	0	0
C-3	2	3.2×10^1
D-1	10	1.60×10^2
D-2	2	3.2×10^1
D-3	6	9.6×10^1
E-1	10	1.60×10^2
E-2	0	0
E-3	6	9.6×10^1
F-1	2	3.2×10^1
F-2	0	0
F-3	4	6.4×10^1
IA-1	1.77×10^4	2.82×10^5
IA-2	2.88×10^4	4.60×10^5
I-IIA-3*		Sampler change
IIA-4**	4.38×10^4	4.38×10^5 (Sampled 8 minutes)
IIA-5	2.95×10^4	4.72×10^5
IIIA-1	2.21×10^4	3.53×10^5
IIIA-2	1.96×10^4	3.13×10^5
III-IVA-3	2.22×10^4	3.55×10^5
IVA-4	4.35×10^4	6.96×10^5
IVA-5	2.05×10^4	3.28×10^5

Table I-2. (CONTINUED)

Sampler identification	Total cells per impinger	Cells per cubic meter of air
VA-1	2.19×10^4	3.50×10^5
VA-2	2.07×10^4	3.31×10^5
V-VIA-3	1.69×10^4	2.70×10^5
VIA-4	1.62×10^4	2.59×10^5
VIA-5	1.67×10^4	2.67×10^5
IB-1	2.11×10^4	3.37×10^5
IB-2	2.04×10^4	3.26×10^5
I-IIB-3	2.09×10^4	3.34×10^5
IIB-4**	3.65×10^4	3.65×10^5 (Sampled 8 minutes)
IIB-5	2.11×10^4	3.37×10^5
IIIB-1	1.87×10^4	2.99×10^5
IIIB-2	1.96×10^4	3.13×10^5
III-IVB-3	2.10×10^4	3.36×10^5
IVB-4	1.93×10^4	3.08×10^5
IVB-5	2.35×10^4	3.76×10^5
VB-1	2.04×10^4	3.26×10^5
VB-2	2.01×10^4	3.21×10^5
V-VIB-3	1.77×10^4	2.83×10^5
VIB-4	1.87×10^4	2.99×10^5
VIB-5	1.78×10^4	2.84×10^5
IC-1	1.40×10^1	2.24×10^2
IC-2	4.00×10^2	6.4×10^3
I-IIC-3	2	3.2×10^1
IIC-4	6.80×10^2	1.09×10^4
IIC-5	2	3.2×10^1
IIIC-1	2.60×10^1	4.16×10^2
IIIC-2	5.00×10^2	8.0×10^3
III-IVC-3	4	6.4×10^1
IVC-4	7.40×10^2	1.18×10^4
IVC-5	2	3.2×10^1
VC-1	1.80×10^1	2.88×10^2
VC-2	6.30×10^2	1.01×10^4
V-VIC-3	1.70×10^2	2.72×10^3
VIC-4	1.24×10^3	1.98×10^4
VIC-5	0	0

Table I-2. (CONTINUED)

Sampler identification	Total cells per impinger	Cells per cubic meter of air
ID-1	0	0
ID-2	0	0
I-IID-3	2	3.2×10^1
IID-4**	1.10×10^2	1.1×10^3 (Sampled 8 minutes)
IID-5	0	0
IIID-1	4	6.4×10^1
IIID-2	2	3.2×10^1
III-IVD-3	0	0
IVD-4	0	0
IVD-5	6	9.6×10^1
VD-1	0	0
VD-2	2	3.2×10^1
V-VID-3	2	3.2×10^1
VID-4	0	0
VID-5	0	0
IE-1	0	0
IE-2	0	0
I-IIE-3	6	9.6×10^1
IIE-4**	0	0 (Sampled 8 minutes)
IIE-5	0	0
IIIE-1	0	0
IIIE-2	2	3.2×10^1
III-IVE-3	0	0
IVE-4	0	0
IVE-5	0	0
VE-1	0	0
VE-2	2	3.2×10
V-VIE-3	0	0
VIE-4	0	0
VIE-5	0	0
IF-1	1.00×10^1	1.6×10^2
IF-2	4	6.4×10^1
I-IIF-3	2.02×10^2	3.23×10^3

Table I-2. (CONCLUDED)

Sampler identification	Total cells per impinger	Cells per cubic meter of air
IIF-4	2	3.2×10^1
IIF-5	2.58×10^2	4.13×10^3
IIIF-1	2	3.2×10^1
IIIF-2	0	0
III-IVF-3	5.04×10^2	8.06×10^3
IVF-4	4	6.4×10^1
IVF-5	7.74×10^2	1.24×10^4
VF-1	0	0
VF-2	0	0
V-VIF-3	4.46×10^2	7.14×10^3
VIF-4	0	0
VIF-5	4.90×10^2	7.84×10^3

* Sample I-IIA-3 was omitted because station A sequencer was changed during the 20- to 25-minute time period of cycle II.

**Samples IIA-4, IIB-4, IID-4, and IIE-4 were aspirated for 8 minutes.

Table I-3. Pre-mission and post-mission swab samples: Challenge No. 1

Station no.	Pre-mission	Post-mission	Station no.	Pre-mission	Post-mission
1	0	0	13	0	0
2	0	1	14	0	0
3	0	2	15	0	0
4	0	0	16	0	0
5	0	0	17	0	0
6	0	0	18	0	0
7	0	0	19	0	3
8	0	0	20	0	3
9	0	1	21	2	2
10	0	0	22	0	4
11	0	0	23	0	4
12	0	0	24	0	2
			25	0	0

BIOLOGICAL SIMULANT CHALLENGE NO. 2: MISSION 2074, 11 March 1969.

1. Pre-mission swab samples taken at 25 pre-determined points

2. Dissemination (6 hours)

Nebulizer no. 1 disseminated 85 ml of slurry at the rate of 0.24 ml/min

Nebulizer no. 2 disseminated 112 ml of slurry at the rate of 0.31 ml/min

The "C" generator disseminated one liter of test agent slurry.

3. Holding Period. No one entered the modification kit during this time. Sampling was initiated one minute after dissemination was begun. Samplers were aspirated according to the following outline:

Time (in minutes)	Samplers operated
0-5	A-1, B-1, C-1, D-1, E-1, F-1
25-30	A-2, B-2, C-2, D-2, E-2, F-2
50-55	A-3, B-3, C-3, D-3, E-3, F-3
75-80	A-4, B-4, C-4, D-4, E-4, F-4
(Impingers changed, stations A and B)	
100-105	A-5, B-5, C-5, D-5, E-5, F-5
125-130	A-6, B-6, C-6, D-6, E-6, F-6

(For results, see Table 1-4.)

4. Pass-through cycles. Eight pass-through cycles were conducted. Impingers were changed after every second cycle. Samplers were aspirated according to the following outline:

A.

Time (in minutes)	Operation
0-5	Samplers IA-1, IB-1, IC-1, ID-1, IE-1, and IF-1 pulled (background).
5-5 1/2	Sampler IC-2 pulled. Volunteer entered chamber C, remained for 10 seconds, and then entered chamber D.

Time (in minutes)	Operation
5 1/2 - 10 1/2	Samplers IA-2, IB-2, ID-2, and IE-2 pulled. Volunteer simulated de-suit in Chamber D. Volunteer took 2-minute shower; then progressed to chamber F when impinger IE-2 stopped.
10 1/2 - 15 1/2	Sampler IF-2 pulled. Volunteer exited chamber F when impinger IF-2 stopped.

(Clock stopped for 30 seconds while volunteer exited shelter.)

16 - 21	Samplers I-IIA-3, I-IIB-3, I-IIC-3, I-IID-3, I-IIE-3, and I-IIF-3 pulled (post-cycle background for pass-through I and pre-cycle background for pass-through II).
21 - 21 1/2	Sampler IIC-4 pulled. Volunteer entered chamber C, remained for 10 seconds, and then entered chamber D.
21 1/2 - 26 1/2	Samplers IIA-4, IIB-4, IID-4, and IIE-4 pulled. Volunteer simulated de-suit in chamber D. Volunteer took 2-minute shower; then progressed to chamber F when impinger IIE-4 stopped.
26 1/2 - 31 1/2	Sampler IIF-4 pulled. Volunteer exited chamber F when impinger IIF-4 stopped.

(Clock stopped for 30 seconds while volunteer exited shelter.)

32 - 37	Samplers IIA-5, IIB-5, IIC-5, IID-5, IIE-5, and IIF-5 pulled (Post-cycle background for pass-through II).

B. Pass-through cycles I and II completed.

C. Impingers for cycles I and II were replaced by impingers for next two cycles.

D. Test continued until eight pass-through cycles were completed. (For results, see Table I-4.)

E. Post-mission swabs were taken. (For results, see Table I-5.)

Table I-4. Aerosol cloud and service module interior concentration data: challenge no. 2

Sampler identification	Total cells per impinger	Cells per cubic meter of air
A-1	1.93×10^5	3.09×10^6
A-2	8.63×10^4	1.38×10^6
A-3	4.68×10^4	7.49×10^5
A-4	3.75×10^4	6.00×10^5
A-5	4.08×10^4	6.53×10^5
A-6	3.58×10^4	5.73×10^5
B-1	1.85×10^5	2.96×10^6
B-2	9.10×10^4	1.46×10^6
B-3	5.43×10^4	8.69×10^5
B-4	4.85×10^4	7.76×10^5
B-5	3.53×10^4	5.65×10^5
B-6	4.10×10^4	6.56×10^5
C-1	2	3.2×10^1
C-2	0	0
C-3	2	3.2×10^1
C-4	2	3.2×10^1
C-5	0	0
C-6	1.00×10^1	1.6×10^2
D-1	2.00×10^1	3.20×10^2
D-2	4	6.4×10^1
D-3	2.60×10^1	4.16×10^2
D-4	6	9.6×10^1
D-5	1.60×10^1	2.56×10^2
D-6	1.80×10^1	2.88×10^2
E-1	4	6.4×10^1
E-2	2.60×10^1	4.16×10^2
E-3	1.40×10^1	2.24×10^2
E-4	0	0
E-5	0	0
E-6	1.20×10^1	1.92×10^2
F-1	2	3.2×10^1
F-2	5.40×10^1	8.65×10^2
F-3	6.00×10^1	9.6×10^2
F-4	8	1.28×10^2
F-5	6	9.6×10^1
F-6	4	6.4×10^1

Table I-4. (CONTINUED)

Sampler identification	Total cells per impinger	Cells per cubic meter of air
IA-1	4.68×10^4	7.49×10^5
IA-2	3.80×10^4	6.08×10^5
I-IIA-3	3.93×10^4	6.29×10^5
IIA-4	4.75×10^4	7.60×10^5
IIA-5	4.15×10^4	6.64×10^5
IIIA-1	4.38×10^4	7.01×10^5
IIIA-2	4.13×10^4	6.61×10^5
III-IVA-3	4.45×10^4	7.12×10^5
IVA-4	3.80×10^4	6.08×10^5
IVA-5	3.30×10^4	5.28×10^5
VA-1	3.20×10^4	5.12×10^5
VA-2	3.38×10^4	5.41×10^5
V-VIA-3	3.30×10^4	5.28×10^5
VIA-4	3.18×10^4	5.09×10^5
VIA-5	3.45×10^4	5.52×10^5
VIIA-1	3.55×10^4	5.68×10^5
VIIA-2	3.35×10^4	5.36×10^5
VII-VIIIA-3	4.08×10^4	6.53×10^5
VIIIA-4	3.18×10^4	5.09×10^5
VIIIA-5	4.63×10^4	7.41×10^5
IB-1	3.85×10^4	6.16×10^5
IB-2	3.65×10^4	5.84×10^5
I-IIB-3	3.28×10^4	5.25×10^5
IIB-4	5.05×10^4	8.08×10^5
IIB-5	4.48×10^4	7.17×10^5
IIIB-1	3.15×10^4	5.04×10^5
IIIB-2	3.00×10^4	4.80×10^5
III-IVB-3	4.03×10^4	6.44×10^5
IVB-4	3.75×10^4	6.00×10^5
IVB-5	2.95×10^4	4.72×10^5
VB-1	3.68×10^4	5.89×10^5
VB-2	4.20×10^4	6.72×10^5
V-VIB-3	3.65×10^4	5.84×10^5
VIB-4	3.30×10^4	5.28×10^5
VIB-5	3.43×10^4	5.49×10^5

Table I-4. (CONTINUED)

Sampler identification	Total cells per impinger	Cells per cubic meter of air
VIIB-1	3.30×10^4	5.28×10^5
VIIB-2	3.18×10^4	5.09×10^5
VII-VIIIB-3	3.33×10^4	5.33×10^5
VIIIB-4	3.50×10^4	5.60×10^5
VIIIB-5	3.78×10^4	6.05×10^5
IC-1	1.80×10^1	2.88×10^2
IC-2	1.76×10^2	2.82×10^4
		(Sampled 30 seconds)
I-IIC-3	4	6.4×10^1
IIC-4	1.52×10^2	2.43×10^4
		(Sampled 30 seconds)
IIC-5	2	3.2×10^1
IIIC-1	5.00×10^1	8.00×10^3
IIIC-2	3.16×10^2	5.06×10^4
		(Sampled 30 seconds)
III-IVC-3	6.60×10^1	1.06×10^3
IVC-4	1.44×10^2	2.30×10^4
		(Sampled 30 seconds)
IVC-5	1.40×10^1	2.24×10^2
VC-1	2.22×10^2	3.55×10^3
VC-2**	2.82×10^2	3.01×10^4
		(Sampled 45 seconds)
V-VIC-3	0	0
VIC-4	3.10×10^2	4.96×10^4
		(Sampled 30 seconds)
VIC-5	2	3.2×10^1
VIIC-1	1.40×10^1	2.24×10^2
VIIC-2	3.96×10^2	6.34×10^4
		(Sampled 30 seconds)
VII-VIIIC-3	8	1.28×10^2
VIIIC-4	3.72×10^2	5.95×10^4
		(Sampled 30 seconds)
VIIIC-5	4	6.4×10^1
ID-1	2	3.2×10^1
ID-2	3.00×10^1	4.8×10^2
I-IID-3	8	1.28×10^2
IID-4	5.80×10^1	9.28×10^2
IID-5	1.70×10^2	2.72×10^2

Table I-4. (CONTINUED)

Sampler identification	Total cells per impinger	Cells per cubic meter of air
IIID-1	0	0
IIID-2	4.20×10^1	6.73×10^2
III-IVD-3	2	3.2×10^1
IVD-4	1.40×10^1	2.24×10^2
IVD-5	2	3.2×10^1
VD-1	0	0
VD-2	1.20×10^1	1.94×10^2
V-VID-3	0	0
VID-4	4.20×10^1	6.73×10^2
VID-5	0	0
VIID-1	0	0
VIID-2	3.40×10^1	5.44×10^2
VII-VIIID-3	0	0
VIID-4	6.00×10^1	9.6×10^2
VIIID-5	0	0
IE-1	2	3.2×10^1
IE-2	4	6.4×10^1
I-IIE-3	2	3.2×10^1
IIE-4	1.60×10^1	2.56×10^2
IIE-5	6	9.6×10^1
IIIE-1	0	0
IIIE-2	1.00×10^1	1.6×10^2
III-IVE-3	2	3.2×10^1
IVE-4	6	9.6×10^1
IVE-5	0	0
VE-1	0	0
VE-2	2.40×10^1	3.84×10^2
V-VIE-3	0	0
VIE-4	2.60×10^1	4.16×10^2
VIE-5	4	6.4×10^1
VIIE-1	0	0
VIIE-2	1.40×10^1	2.24×10^2
VII-VIIIE-3	2	3.2×10^1
VIIIE-4	3.20×10^1	5.12×10^2
VIIIE-5	0	0

Table I-4. (CONCLUDED)

Sampler identification	Total cells per impinger	Cells per cubic meter of air
IF-1	1.00×10^1	1.6×10^2
IF-2	0	0
I-IIF-3	1.44×10^3	2.30×10^4
IIF-4*	0	0 (Sampled 4 minutes)
IIF-5	1.67×10^3	2.67×10^4
IIIF-1	4.00×10^1	6.4×10^2
IIIF-2	0	0
III-IVF-3	1.04×10^3	1.67×10^4
IVF-4*	0	0 (Sampled 4 minutes)
IVF-5	1.37×10^3	2.19×10^4
VF-1	6.00×10^1	9.6×10^2
VF-2***	1.20×10^3	1.92×10^4
V-VIF-3	7.00×10^1	1.12×10^3
VIF-4	0	0
VIF-5	1.55×10^3	2.48×10^4
VIIF-1	3.28×10^2	5.25×10^3
VIIF-2	0	0
VII-VIIIF-3	1.31×10^3	2.1×10^4
VIIIF-4	6	9.6×10^1
VIIIF-5	1.84×10^3	2.94×10^4

* Samplers IIF-4 and IVF-4 were aspirated for 4 minutes.
** Sampler VC-2 was aspirated for 45 seconds.
***While sample VF-2 was being taken, volunteer exited chamber F early.

Table I-5. Pre-mission and post-mission swab samples: Challenge No. 2

Swab no.	Pre-mission	Post-mission	Swab no.	Pre-mission	Post-mission
1	1	0	13	0	0
2	0	0	14	0	0
3	0	12	15	0	0
4	0	0	16	0	0
5	0	0	17	0	0
6	0	0	18	0	0
7	0	4	19	0	0
8	0	0	20	1	0
9	0	0	21	0	15
10	0	0	22	0	1
11	0	0	23	0	13
12	0	0	24	0	10
			25	0	8

APPENDIX II

CHEMICAL SIMULANT TESTING OF THE CB MODIFICATION KIT FOR STRUCTURES

SUMMARY OF DISSEMINATION, SAMPLING, AND ASSAY PROCEDURES

Two types of disseminators were used to produce and maintain the required concentration of Methyl Acetoacetate (MAA). Approximately 500 grams of MAA were disseminated by the "C" generator to produce the initial concentration. Two Devilbus nebulizers disseminating approximately 2 grams per minute were used to maintain concentration. Since this was not sufficient to maintain the required 100 milligrams per cubic meter, the "C" generator was used to disseminate 250-gram quantities of MAA at two-hour intervals throughout the test.

All glass impingers were aspirated at 12.5 liters per minute. These contained 20 milliliters n-octyl alcohol as a collecting fluid. Pre-impingers were not used. All samplers were aspirated for approximately five minutes with the exception of even-numbered samplers at station C, which were aspirated for 0.5 minutes.

Following sampling, impingers were returned to the laboratory for analysis. Additional quantities of n-octyl alcohol were added to bring the total volume of each impinger to 30 milliliters. The contents of each impinger were transferred to a 10-centimeter cell and observed on the DK2A spectrophotometer. Observations were conducted at a wave length of 245 millimicrons, the absorption peak for MAA in n-octyl alcohol, and at 300 millimicrons, where MAA does not absorb. Absorbance readings at 300 millimicrons were attributed to dust and were subtracted from the 245 reading to obtain net absorbance due to the presence of MAA. Net readings were compared with those obtained by the preparation of a calibration curve. Based on this comparison, absorbance reading was converted to quantity of MAA per impinger. The quantity of MAA per impinger was divided by the fraction of a cubic meter sampled to provide an estimate of MAA concentrations in milligrams per cubic meter.

Additional impingers, aspirated prior to the introduction of MAA into the shelter, were used as backgrounds.

The contents of these impingers were observed on the spectrophotometer. Background readings were converted to equivalent quantity of MAA per impinger. The average background was equivalent to 0.015 milligram of Methyl Acetoacetate per impinger $\pm$ 0.015 milligram of Methyl Acetoacetate per impinger.

The chemical simulant challenges were conducted using the same procedure as the second biological simulant challenge, and samplers were labeled in the same manner (see Appendix I). Results of the first chemical simulant challenge are contained in Table II-1, and the results of the second chemical simulant challenge are contained in Table II-2.

Swab samples were taken during the first chemical simulant challenge. Due to inconclusive results the requirement was deleted from the second challenge, and the results are not included in this report.

Table II-1. Aerosol cloud and service module interior concentration data: Challenge no. 1

Station	mg MAA/impinger	Sampling time (min)	[illegible] MAA/m3
A-1	11.2	5.33	1[illegible]7
B-1	10.3	5.33	154
C-1	Contaminated	5.33	Contaminated
D-1	< 0.015	5.33	< 0.2
E-1	< 0.015	5.33	< 0.2
F-1	< 0.015	5.33	< 0.2
A-2	7.86	5.0	126
B-2	4.91	5.0	78.6
C-2	< 0.015	5.0	< 0.2
D-2	0.020	5.0	0.3
E-2	< 0.015	5.0	< 0.2
F-2	< 0.015	5.0	< 0.2
A-3	3.49	5.0	55.9
B-3	3.39	5.0	54.2
C-3	< 0.015	5.0	< 0.2
D-3	< 0.015	5.0	< 0.2
E-3	< 0.015	5.0	< 0.2
F-3	< 0.015	5.0	< 0.2

Table II-1. (Continued)

Station	mg MAA/impinger	Sampling time (min)	mg MAA/m^3
A-4	3.06	5.0	48.9
B-4	3.06	5.0	48.9
C-4	< 0.015	5.0	< 0.2
D-4	< 0.015	5.0	< 0.2
E-4	< 0.015	5.0	< 0.2
F-4	< 0.015	5.0	< 0.2
A-5	2.89	5.0	46.3
B-5	3.00	5.0	48.0
C-5	< 0.015	5.0	< 0.2
D-5	< 0.015	5.0	< 0.2
E-5	< 0.015	5.0	< 0.2
F-5	< 0.015	5.0	< 0.2
A-6	2.78	5.0	44.5
B-6	2.67	5.0	42.8
C-6	< 0.015	5.0	< 0.2
D-6	< 0.015	5.0	< 0.2
E-6	< 0.015	5.0	< 0.2
F-6	< 0.015	5.0	< 0.2

Table II-1. (Continued)

Station	mg MAA/impinger	Sampling time (min)	mg MAA/m3
I A-1	4.91	5.0	78.6
I B-1	4.86	5.0	77.8
I C-1	Contaminated		
I D-1	< 0.015	5.0	< 0.2
I E-1	< 0.015	5.0	< 0.2
I F-1	< 0.015	5.0	< 0.2
I C-2	0.045	0.50	6.3
I A-2	4.58	5.0	73.4
I B-2	4.48	5.0	71.6
I D-2	< 0.015	5.0	< 0.2
I E-2	< 0.015	5.0	< 0.2
I F-2	< 0.015	5.0	< 0.2
I II A-3	4.97	5.5	72.3
I II B-3	4.04	5.5	58.5
I II C-3	< 0.015	5.5	< 0.2
I II D-3	< 0.015	5.5	< 0.2

Table II-1. (Continued)

Station	mg MAA/impinger	Sampling time (min)	mg MAA/m^3
I II E-3	< 0.015	5.5	< 0.2
I II F-3	0.155	5.5	2.3
II C-4	0.040	0.50	6.0
II A-4	4.42	5.0	70.8
II B-4	3.93	5.0	62.9
II D-4	< 0.015	5.0	< 0.2
II E-4	< 0.015	5.0	< 0.2
II F-4	0.035	5.0	0.5
II A-5	3.82	5.0	61.2
II B-5	3.11	5.0	49.8
II C-5	< 0.015	5.0	< 0.2
II D-5	< 0.015	5.0	< 0.2
II E-5	< 0.015	5.0	< 0.2
II F-5	0.128	5.0	1.9
III A-1	3.17	5.0	50.7

Table II-1. (Continued)

Station	mg MAA/impinger	Sampling time (min)	mg MAA/m3
III B-1	2.73	5.0	43.7
III C-1	< 0.015	5.0	< 0.2
III D-1	Sampler malfunction		
III E-1	< 0.015	5.0	< 0.2
III F-1	< 0.025	5.0	0.4
III C-2	0.035	0.5	5.5
III A-2	3.06	5.0	48.9
III B-2	2.67	5.0	42.8
III D-2	Sampler malfunction		
III E-2	< 0.015	5.0	< 0.2
III F-2	0.020	5.0	0.3
III IV A-3	3.00	5.0	48.0
III IV B-3	2.51	5.0	40.2
III IV C-3	< 0.015	5.0	< 0.2
III IV D-3	Sampler malfunction		
III IV E-3	< 0.015	5.0	< 0.2

Table II-1. (Continued)

Station	mg MAA/impinger	Sampling time (min)	mg MAA/m3
III IV F-3	0.115	5.0	1.9
IV C-4	0.035	0.50	5.5
IV A-4	3.06	5.0	48.9
IV B-4	Sampler broken		
IV D-4	Sampler malfunction		
IV E-4	< 0.015	5.0	< 0.2
IV F-4	0.015	5.0	0.2
IV A-5	2.95	5.0	47.2
IV B-5	2.62	5.0	41.9
IV C-5	< 0.015	5.0	< 0.2
IV D-5	Sampler malfunction		
IV E-5	< 0.015	5.0	< 0.2
IV F-5	0.080	5.0	1.3
V A-1	Missing		
V B-1	0.97	5.0	15.6
V C-1	0.95	5.0	15.2*

Table II-1. (Continued)

Station	mg MAA/impinger	Sampling time (min)	mg MAA/m^3
V D-1	< 0.015	5.0	< 0.2
V E-1	< 0.015	5.0	< 0.2
V F-1	< 0.015	5.0	0.2
V C-2	0.90	0.5	144 *
V A-2	1.04**	5.0	16.6
V B-2	2.62	5.0	41.9
V D-2	< 0.015	5.0	< 0.2
V E-2	< 0.015	5.0	< 0.2
V F-2	< 0.015	5.0	< 0.2
V VI A-3	6.33	5.0	101
V VI B-3	6.61	5.0	106
V VI C-3	0.983	5.0	15.7 *
V VI D-3	< 0.015	5.0	< 0.2
V VI E-3	< 0.015	5.0	< 0.2
V VI F-3	0.215	5.0	3.5

Table II-1. (Concluded)

Station	mg MAA/impinger	Sampling time (min)	mg MAA/m3
VI C-4	0.172	0.5	27.6 *
VI A-4	5.35	5.0	85.6
VI B-4	5.51	5.0	88.2
VI D-4	< 0.015	5.0	< 0.2
VI E-4	< 0.015	5.0	< 0.2
VI F-4	< 0.015	5.0	< 0.2
VI A-5	4.31	5.0	69.0
VI B-5	3.98	5.0	63.8
VI C-5	1.06	5.0	17.0*
VI D-5	< 0.015	5.0	< 0.2
VI E-5	< 0.015	5.0	< 0.2
VI F-5	0.180	5.0	2.9

* Sampler contamination suspected
** Volume loss

Table II-2. Aerosol cloud and service module interior concentration: challenge no. 2

Station	mg MAA/impinger	Sampling time (min)	mg MAA/m3
I A-1	6.33	5.0	101
I B-1	6.88	5.0	110
I C-1	< 0.015	5.0	< 0.2
I D-1	< 0.015	5.0	< 0.2
I E-1	< 0.015	5.0	< 0.2
I F-1	< 0.015	5.0	< 0.2
I C-2	0.067	0.50	10.7
I A-2	5.46	5.0	87.0
I B-2	5.24	5.0	83.6
I D-2	< 0.015	5.0	< 0.2
I E-2	< 0.015	5.0	< 0.2
I F-2	< 0.015	5.0	< 0.2
I II A-3	3.60	5.0	57.4
I II B-3	3.38	5.0	53.8
I II C-3	< 0.015	5.0	< 0.2
I II D-3	< 0.015	5.0	< 0.2

Table II-2. (Continued)

Station	mg MAA/impinger	Sampling time (min)	mg MAA/m³
I II E-3	< 0.015	5.0	< 0.2
I II F-3	0.023	5.0	2.0
II C-4	0.052	0.5	8.2
II A-4	3.06	5.0	48.7
II B-4	3.28	5.0	52.2
II D-4	Sampler malfunction		
II E-4	< 0.015	5.0	< 0.2
II F-4	< 0.015	5.0	< 0.2
II A-5	2.28	5.0	36.4
II B-5	2.60	5.0	41.7
II C-5	< 0.015	5.0	< 0.2
II D-5	< 0.015	5.0	< 0.2
II E-5	< 0.015	5.0	< 0.2
II F-5	< 0.015	5.0	< 0.2
III A-1	4.57	5.0	73.2

Table II-2. (Continued)

Station	mg MAA/impinger	Sampling time (min)	mg MAA/m^3
III B-1	4.56	5.0	73.0
III C-1	< 0.015	5.0	< 0.2
III D-1	< 0.015	5.0	< 0.2
III E-1	< 0.015	5.0	< 0.2
III F-1	< 0.015	5.0	< 0.2
III C-2	0.077	0.5	12.3
III A-2	4.02	5.0	64.4
III B-2	3.47	5.0	55.6
III D-2	0.070	5.0	1.1
III E-2	< 0.015	5.0	< 0.2
III F-2	< 0.015	5.0	< 0.2
III IV A-3	2.44	5.0	39.1
III IV B-3	2.12	5.0	33.8
III IV C-3	< 0.015	5.0	< 0.2
III IV D-3	0.040	5.0	0.6
III IV E-3	< 0.015	5.0	< 0.2

Table II-2. (Continued)

Station	mg MAA/impinger	Sampling time (min)	mg MAA/m^3
III IV F-3	0.076	5.0	1.2
IV C-4	< 0.015	0.5	< 2.0
IV A-4	1.79	5.0	28.6
IV B-4	2.00	5.0	32.0
IV D-4	Sampler malfunction		
IV E-4	< 0.015	5.0	< 0.2
IV F-4	< 0.015	5.0	< 0.2
IV A-5	1.78	5.0	28.5
IV B-5	1.57	5.0	25.0
IV C-5	< 0.015	5.0	< 0.2
IV D-5	< 0.015	5.0	< 0.2
IV E-5	< 0.015	5.0	< 0.2
IV F-5	0.063	5.0	1.0
V A-1	4.40	5.0	70.5
V B-1	4.90	5.0	78.3

Table II-2. (Continued)

Station	mg MAA/impinger	Sampling time (min)	mg MAA/m3
V C-1	< 0.015	5.0	< 0.2
V D-1	< 0.015	5.0	< 0.2
V E-1	< 0.015	5.0	< 0.2
V F-1	< 0.015	5.0	< 0.2
V C-2	0.082	0.5	13.2
V A-2	2.99	5.0	47.8
V B-2	3.35	5.0	53.7
V D-2	< 0.015	5.0	< 0.2
V E-2	< 0.015	5.0	< 0.2
V F-2	< 0.015	5.0	< 0.2
V VI A-3	2.38	5.0	38.2
V VI B-3	1.98	5.0	31.8
V VI C-3	0.015	5.0	< 0.2
V VI D-3	0.030	5.0	0.4
V VI E-3	< 0.015	5.0	< 0.2
V VI F-3	0.025	5.0	0.4

Table II-2. (Continued)

Station	mg MAA/impinger	Sampling time (min)	mg MAA/m3
VI C-4	Sampler malfunction		
VI A-4	1.90	5.0	30.3
VI B-4	1.59	5.0	25.4
VI D-4	< 0.015	5.0	< 0.2
VI E-4	< 0.015	5.0	< 0.2
VI F-4	Sampling time unknown		
VI A-5	Sampling time unknown		
VI B-5	Sampling time unknown		
VI C-5	Sample missing		
VI D-5	< 0.015	5.0	< 0.2
VI E-5	< 0.015	5.0	< 0.2
VI F-5	Sampling time unknown		
VII A-1	0.93	5.0	15.0
VII B-1	0.94	5.0	15.0
VII C-1	0.015	5.0	0.2
VII D-1	< 0.015	5.0	< 0.2

Table II-2. (Concluded)

Station	mg MAA/impinger	Sampling time (min)	mg MAA/m³
VII E-1	< 0.015	5.0	< 0.2
VII F-1	0.063	5.0	1.0
VII C-2	Sampler malfunction		
VII A-2	0.88	5.0	14.0
VII B-2	.94	5.0	15.0
VII D-2	< 0.015	5.0	< 0.2
VII E-2	< 0.015	5.0	< 0.2
VII F-2	0.125	5.0	2.0
VII VIII A-3	Contaminated		
VII VIII B-3	0.72	5.0	11.5
VII VIII C-3	< 0.015	5.0	< 0.2
VII VIII D-3	< 0.015	5.0	< 0.2
VII VIII E-3	< 0.015	5.0	< 0.2
VII VIII F-3	0.635	5.0	10.2

APPENDIX III

HUMAN FACTORS ENGINEERING EVALUATION OF THE CHEMICAL AND BIOLOGICAL (CB) MODIFICATION KIT FOR STRUCTURES

by

Charles V. Durham, Capt, USAF

INTRODUCTION

The Air Force Armament Laboratory, through Project Directive 3762W004, requested that this Division evaluate the CB Modification Kit for Structures from a human factors standpoint. The data for this evaluation was collected during the Eglin test of the system.

The evaluation is divided into four parts:

1. CB Modification Kit Design
2. System Controls — Design and Location
3. Equipment/Control Labeling
4. Biomedical (Personnel Safety) Aspects of the System.

TEST PROCEDURES

The human factors engineer assigned to this project observed test subjects as they were required to utilize the modification kit. Subsequent to actual shelter pass-throughs, test subjects were interviewed concerning any problems encountered during their use of the system. Pertinent comments made by test subjects and on-the-spot data, recorded by the human factors engineer, were used in evaluation of the system. Project personnel other than test subjects also were interviewed and contributed to the subsequent data pool.

Existing design features of the modification kit were compared to recommended design characteristics as presented in Air Force military standards and design handbooks relating to human factors.

TEST RESULTS AND DISCUSSION

MODIFICATION KIT DESIGN

Considering the limited amount of space available in a shelter of the type being tested, allocation of space and compartmentalization are adequate. Test subjects and project personnel working with the shelter are well pleased with its roominess for the tasks that must be performed.

From the human factors viewpoint (i.e., primary consideration being given to the "man" in the man/machine interface process), the allocation of space and the personnel/performance flow required by the system is very well organized. However, the modification kit does present a few minor, but nevertheless, important problems.

Consider initially, for example, the selection of an area for set-up of the modification kit. Locally, geographical placement of the unit was not difficult since relatively level ground was readily available. Because of this, the question of whether the unit needed to be leveled before operation was not important. Project personnel have stated, however, that the kit is primarily fabricated from aluminum for durability without weight. Contractor personnel have stated that, because of its lightweight construction, the unit must be erected on relatively level ground (i.e., kit weight must be uniformly distributed on its base) or the framework of the unit may distort and cause the doors of the kit to become inoperable. As far as can be determined, even though there is a requirement for a level area for kit emplacement, no guidelines are available for this requirement. Specific limits in this regard should be available for operator personnel in a field situation. This would prevent confusion, reduce kit erection time, and insure proper kit erection.

The CB modification kit has incorporated an emergency lighting unit near the exit airlocks (unit faces the shower stall). This unit has not been used during the testing phase at Eglin AFB. It is considered a necessary unit, however, and consequently should be installed correctly.

As presently attached, the small meter located on the unit to indicate battery charge is on the underside of the outer casing, oriented toward the modification kit floor. In other words, a person desiring to read the meter display would be required to stand directly under the light. The indicator is not readable from any other part of the kit. This, of course, eliminates the possibility of making quick check readings of the lamp and also requires that the person involved move to the lamp, crouch under it, and make the reading.

The kit heater unit is located in a perforated door which separates the service module from the exit passageway (see Figure III-1). The heater is so located to enable rapid convective heating of the modification kit by the action of the blower units which port into the exit passageway.

During decontamination procedures the kit heater should maintain the inner temperature within a specified comfort range. MIL-STD 803A-2,[1] page 37, states:

> "Temperature should be variable according to the worker's physical activity and clothing. For personnel engaged in light work, the ambient temperature should be between 68°F and 82°F, with moderate relative humidity (approximately 45%), and air movement of 15 to 25 feet per minute."

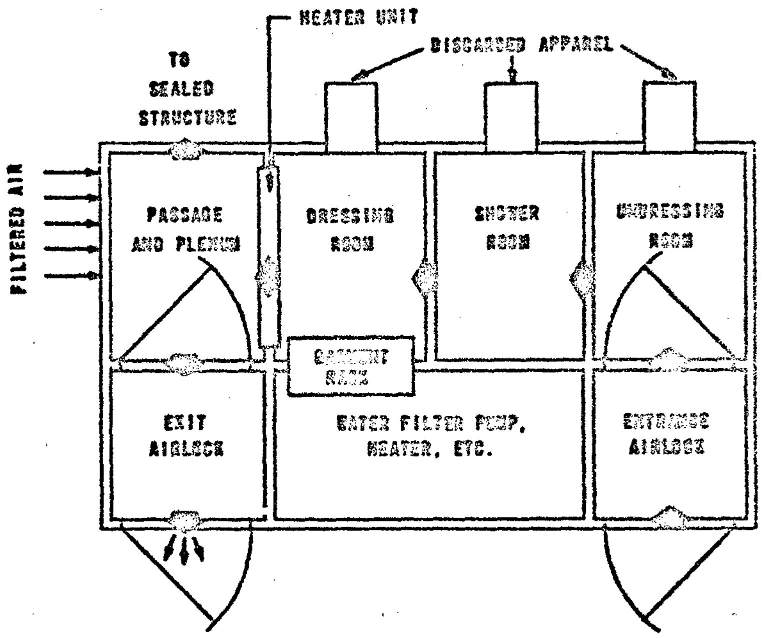

Figure III-1. CB Modification Kit floor plan (reproduced from Phase II Design Evaluation Report, 22 January 1968)

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1. Human engineering Design Criteria for Aerospace Systems and Equipment, PART 2, Aerospace System Facilities and Facility Equipment, dated 1 [illegible] 1964. (This document has been superceded, but the information presented is relevant and applicable.)

It is imperative that the heater within the kit be of sufficient size to allow the maintenance of temperature at least up to the 82°F point. This is necessitated by the fact that personnel could be required to remove all their clothing for decontamination (which would include a shower) prior to entry into a decontaminated structure.

During environmental testing of the modification kit, it was placed inside the Climatic Laboratory chamber and the temperature was lowered to -22°F. At this temperature, the internal heater at full operation, with sufficient time to heat the kit, provided the following temperatures in the shelter. (See Figure III-1 for location of modification kit compartments listed in Table III-1.)

Table III-1. Temperature readings taken in compartments within the modification kit. Ambient (chamber) temperature was -22°F.

Compartment	Type of readings taken	Temperatures (°F)*
Entrance airlock	Air	+16 to +20
Undressing room	Air	+6 to +24
	Floor	+2 to +30
Shower	Floor	+27 to +78
Dressing room	Air	+15 to +30
	Floor	+8 to +12
Exit airlock	Air	+8 to +12

* Temperature fluctuation was caused by the heating action of the shower.

CONTROL DESIGN AND LOCATION

There are a limited number of controls which must be operated by individuals utilizing the modification kit. They may be divided into two groups: those requiring operation during a decontamination exercise (i.e., door handles, shower controls, etc.) and those which can be preset and are generally not manipulated by personnel passing through the kit (i.e., warning light timing cycle, water heater temperature setting, etc.)

The majority of controls in the former group are well designed and located. One exception to this is the kit heater/temperature control knob which is located on the side of the control panel within the shelter.

The control is designed and located appropriately but when it was installed in the kit a hole was drilled through the control scale and a screw passed through this hole to attach the unit to the wall. The control and scale now appear as shown in Figure III-2. MIL-STD 1472,[2] page 68, states that the primary purpose for scales of the type being discussed is to enable quick, easy settings of the control and to eliminate confusion. These purposes are not fulfilled by the present heater control scale.

Of the pre-set shelter controls, the most poorly designed are the rotary selector knobs used to set the time delay for the ENTER and WAIT lights located in the entry airlock. These controls are located in junction box no. 1 near the water heater within the service area of the shelter. Project test personnel have stated that the control scales are not correct.[3]

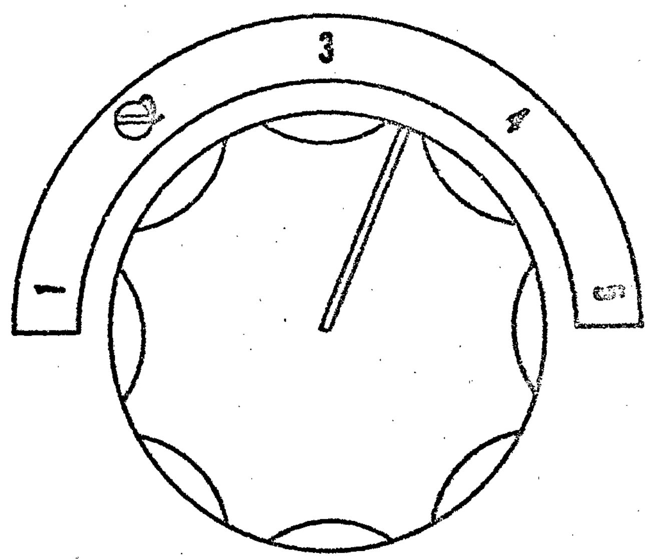

Figure III-2. Modification kit heater control knob as presently configured (Note screw head located near scale no. 2.)

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2. Human Engineering Design Criteria for Military Systems, Equipment and Facilities, dated 9 February 1968.

3. These control units are off-the-shelf items. The indicated [illegible] are not calibrated in seconds; hence, they are meaningless for the settings required in the modification kit.

The two controls (one for each of the lights) are not marked, and it is impossible to tell which control services which light. Also, their present location prevents easy access. With the shelter in operation a shelf unit is affixed in front of this particular junction box and control adjustment would require complete removal of this unit for access.[4] MIL-STD 1472, page 67, states in regard to the above points that,

> "Controls, displays, and other items of equipment that must be located, identified, read or manipulated shall be appropriately and clearly (marked) labeled to permit rapid and accurate human performance."

LABELING

The inner door of the kit entry airlock has no man-operated access latch (i.e., no hand-actuated access device). The inner door is mechanically interlocked with the outer door, however, and when the airlock is entered, the inner door will not become operable until the outer door is closed. The mechanical interlock is then released, and the inner door may be opened by a push. (Reference Figure III-1.)

Located on the inner door is a small (approximately 8 inches by 3 inches) metal push panel which may be used to gain entry, when appropriate, into the service area. This push panel, however, is designed as though it should be pulled to allow entry into the service area. At its base is a curved lip which implies that the hand is to be inserted and the door is to be pulled open.

There is no labeling in the access airlock which indicates correct door movement. Personnel consistently attempt to pull the door open on their first and, occasionally subsequent shelter pass-throughs.

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4. It is realized that these controls are pre-set and are not to be manipulated by personnel passing through the shelter. However, when changes in control settings are required, they should be effected as quickly as possible. The present location of these controls prevents quick, easy manipulation.

It is realized that the push plates/[illegible] of the [illegible] airlock doors were probably off-the-shelf and inexpensive items. [illegible] present design, however, confusion can result and valuable time [illegible] when using the system.[5]

The timer units controlling delay between [illegible] and ENTER light illumination are not labeled properly [illegible] discussed previously in the report.

The shower controls ([illegible] and water [illegible] ment) are well designed and located [illegible] appropriately. Model no. 1 of the [illegible] for the two cited controls. Model no. 2 [illegible] During the chemical simulant testing of [illegible] viewed subsequent to his hot [illegible] protective clothing, typical of [illegible] concerning his difficulty in adjusting the water temperature [illegible] to show correct control movement for either [illegible] subject was required to shower while wearing his protective [illegible] subject's answer was that he had no difficulty at all. [illegible] temperature control until he sensed the water [illegible] in the protective suit (he was sensing through the entire [illegible] have been scalded. If, under operational conditions, [illegible] because several people were [illegible] with no label or control [illegible] be showered with extremely hot water [illegible] ment.

Unlike a shower at home, the [illegible] extremely confined ([illegible] He cannot stick his hand in to adjust the water [illegible] exit if the water becomes too cold or too hot. He must [illegible] shower to turn it on and [illegible] until he [illegible] like the temperature. Common sense and AF military [illegible] this is not a desirable condition.[6]

---

5. Occasionally personnel may be required to [illegible] entrance [illegible]
[illegible]

[illegible] ASPECTS

[illegible] II Design Evaluation Report, CR Modification Kit for [illegible] Field [illegible], dated 22 January 19[illegible], pages 23, 24, [illegible] that the Contaminated Articles Disposal Chutes should [illegible] a [illegible]-door configuration which would enable contaminated art[illegible] disposed without allowing contaminated air to enter the service [illegible] shelter. Subsequent to the cited report, this double-door con[illegible] was altered. The disposal chutes now consist of small throughs [illegible] wall of the shelter. A small internal shelter door opens into [illegible], in an operational situation, a plastic bag would be taped [illegible] as a receptacle for the contaminated items.

[illegible] would seem highly possible [illegible] one or more of these bags could [illegible] from its trough, allowing [illegible] contaminated air access to the shelter [illegible] (High winds, for example, could conceivably remove a bag from [illegible].) Action of the blower units would probably prevent seepage of [illegible] air around the chute door. The door could be opened for de[illegible] contaminated clothing, however, and the blower probably could not [illegible] counteract the rush of contaminated air. This could lead [illegible] of the service module.

[illegible] final point concerning the biomedical aspects of the kit relates [illegible] inside the unit when the blowers are attached and in [illegible]. In testing at Eglin AFB, a single blower was used and the noise [illegible]. ([illegible] of the noise were not taken due to the [illegible] which the unit was being tested.)

[illegible] (not physically attached) location of blowers [illegible] it is not expected that the noise created would be of con[illegible] the [illegible]. Measurements should be taken, however, if con[illegible], [illegible], Hazardous Noise Exposure, dated 29 October [illegible] a [illegible] of the noise problem and also provides a [illegible] of noise exposure limits to be applied to Air Force systems.

[illegible]

[illegible] and control requirements for the [illegible] on [illegible] are not available with the [illegible]

[illegible]

3. The modification kit heater is not of sufficient size to warm the shelter as required.

4. The heater/temperature control scale is not designed to allow efficient adjustment and reading.

5. The modification kit ENTER and WAIT light controls do not have proper scales, are not marked as to their respective functions, and are not located for easy access.

6. The access door leading from the entry airlock into the service module is not marked to indicate entry procedure.

7. The modification kit shower controls are not labeled.

RECOMMENDATIONS

1. Level limitations or contour requirements for the ground on which the modification kit is to be installed should be placed in the appropriate section (i. e., system erection/installation procedures) of the technical manual published for this system. Also, if any special tools (i.e., level indicators, etc.) are needed to determine or effect these requirements, they should be issued as part of the kit equipment. (The level indicators could be permanently mounted on the shelters, as in other systems such as the 407L Tactical Air Control System.)

2. A special bracket should be built for the emergency lighting units. The bracket could be constructed so the unit could be mounted vertically, enabling efficient check readings of its incorporated status meter.

3. The kit heater should be increased in size to insure adequate internal temperature ranges for personnel use during inclement weather.

4. The modification kit heater/temperature control should be affixed to the wall in a manner which eliminates the need to obliterate a portion of the control scale.

5. The modification kit ENTER and WAIT light controls should be modified as follows:

a. The scales should be redesigned for use in controlling and setting time indications in seconds.

b. Each of the two controls should be marked to indicate which light (ENTER or WAIT) it services.

c. The controls should be mounted for easier access. A simple correction might be to cut an opening in the rear of the shelve unit (large enough to enable access to junction box no. 1) to preclude removal of that unit when setting the controls.

6. The access door from the entry airlock to the service module of the kit should be labeled PUSH TO OPEN.

7. The modification kit shower controls should be labeled according to their functions and directional movements required for alteration of water temperature.

8. A dual-door configuration (similar to that recommended in the Phase II report, page 23) should be incorporated in the contaminated clothing disposal chutes. It is realized that the original design (as in the Phase II report) could not be incorporated because of specifications as to overall shelter size. A similar configuration should be arranged, however, to eliminate the possibility of modification kit contamination.

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13. ABSTRACT

An engineering evaluation was conducted on the CB Modification Kit ~~for Structures~~. Environmental testing ~~demonstrated the ability of the system to withstand extremes of~~ temperature, dust, and rain. Floor buckling and corrosion prevented operation after humidity testing. CB simulant testing demonstrated that the system meets design requirements and will protect personnel with 99.6 percent efficiency in chemical simulant (Methyl Acetoacetate) concentrations up to 100 mg/m^3 and with 99.99 percent efficiency in biological simulant (Bacillus globigii) concentrations up to 10^6 $cells/m^3$. A C-123 aircraft will accommodate the service module and 3 filter-blower units.

was performed; temperature, dust, rain, floor buckling and corrosion tests were carried out.

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KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Chemical and biological modification kit						
Extreme temperature environment						
C-123 air transportability						
Personnel decontamination						

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